FIND OUT WHICH ANIMAL LIVES LONGEST

HOW IT WORKS

WHAT WOULD HAPPEN IF THE MOON EXPLODED?

SCIENCE ENVIRONMENT TECHNOLOGY TF HIST RY SPACE

HOW TO HACK A HUMAN

Discover the tech that will transform your body

DEVASTATING SPEED

CUTTING-EDGE BATTLE TECH

WEIRD WORLD WONDERS

The bizarre and beautiful landscapes of Earth explained

SPACE LASERS

Guiding giant telescopes with beams of light

AWESOME FIREPOWER

ARMED & DANGEROUS ATTACK HELICOPTERS

THE DEADLY GUNSHIPS ELIMINATING THE ENEMY FROM ABOVE

SCIENCE FROM NATURE

How plants and animals give engineering solutions

SATURN'S ATMOSPHERE

What makes up this ringed gas giant?

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HOW THE HEART BEATS

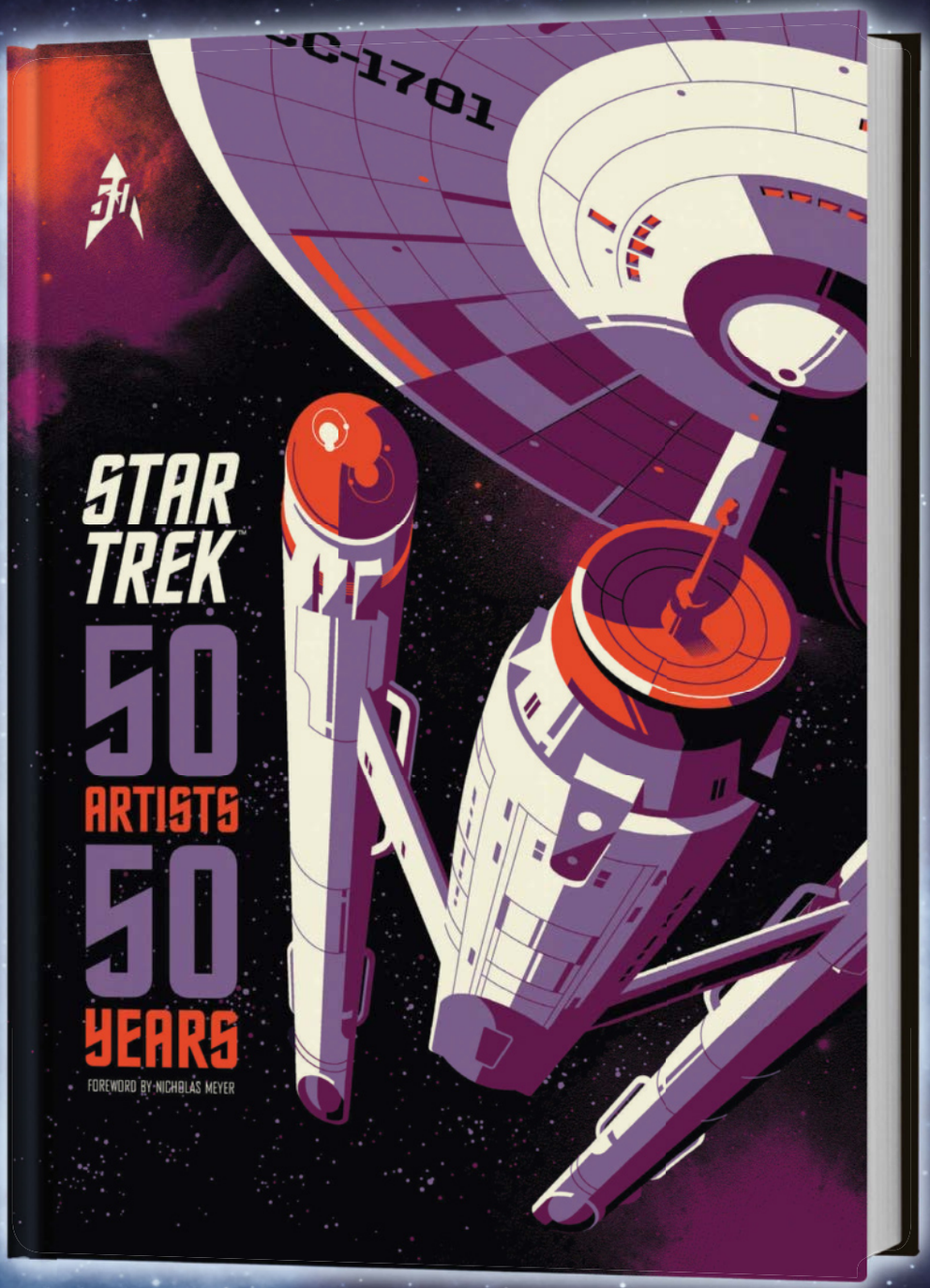
Discover exactly what keeps your ticker ticking

VIKING FUNERALS

How Nordic warriors were sent to the afterlife

+ LEARN ABOUT KITESURFING TRAIN TRACKS XBOX ONE S FABERGÉ EGGS SOYUZ GLIDERS

SET YOUR EYES TO STUNNED!



To celebrate the 50th anniversary of the beloved series, this gorgeous art book features a specially commissioned collection of art pieces from fans and artists around the world!

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ISSUE 91

WELCOME

The magazine that feeds minds!

"This geometric landscape formed over millions of years of geological activity"

Weird world wonders, page 26

Meet the team...

Dave
Editor-in-Chief
I'm old enough to remember the 1980s, so I was a massive fan of *Airwolf* as a kid. Hence, the main feature on attack helicopters has got me in a spin this issue!

Katy
Research Editor
If the Moon doesn't explode, the Sun eventually will – but we might face asteroid oblivion first! Meet our violent universe on page 64.

Jack
Senior Staff Writer
I've only recently recovered from my $1,500-a-day Fabergé egg habit, but it was fascinating to discover the history of these rare ornaments.

James
Staff Writer
Imagine a world where we can generate power with artificial leaves. Find out how scientists are developing amazing technology inspired by nature over on page 52.

Duncan
Senior Art Editor
I've jusst reccently had my ammazing neww high-techh mmmaagneticc fffinggger tiiiipsss fittted, tthey arre takingg soomee gettingg ussed tooo!!!!

Laurie
Assistant Designer
Want an example of team work? It takes Formula One crews less than three seconds to turn a car around on race day – that crew moves seriously fast!

FOLLOW US... How It Works magazine @HowItWorksmag

If, like me, you're no stranger to thrilling your friends with comments about the defined sedimentary layers of a cliff face, then you'll love this month's environment feature. Unleash your inner geologist as we explore the planet's strangest rock formations in 'Weird world wonders'. From the imposing monoliths of Uluru and Devils Tower, to the otherworldly terrains of the Giant's Causeway and Pinnacles Desert, you'll find plenty of places to add to your travel wish-list.

This issue, Jack tackles transport to tell us all about the tech on board attack helicopters, while our new writer, James, explains how nature can inspire simple solutions to our science and engineering problems.

Also this month, we explore the DIY-biotech revolution of biohacking, take a tour of the extravagant Palace of Versailles, and bring a little existential dread to the magazine with our space feature, 'Cosmic catastrophes', on page 64.

Enjoy the issue!

Jackie **Jackie Snowden**
Deputy Editor

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72 The Soyuz spacecraft

81 Medieval jobs

Meet the experts...

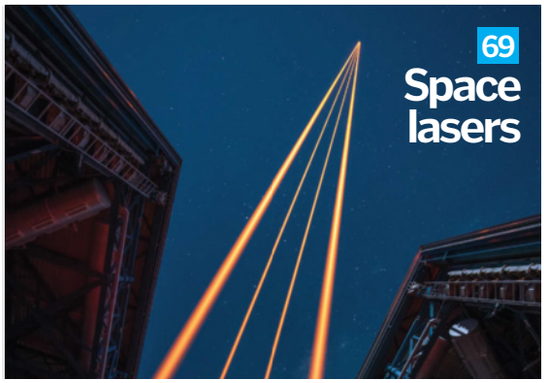
Jonathan O'Callaghan
This issue, Jonny talks us through the dangerous and deadly events that occur throughout the universe in 'cosmic catastrophes'. He also explains how the Soyuz has survived nearly 50 years in service.

Laura Mears
Laura reveals how 'biohackers' are changing what it means to be human by augmenting their bodies with tech. She also warns us about the harm of wearing high heels on page 63.

Joanna Stass
This month, Jo takes a world tour of geological wonders in our environment feature. She also reveals the differences between tree kangaroos and their land-dwelling relatives.

Laurie Winkless
Laurie explains how pressure cookers produce delicious meals in mere minutes. She also takes to the skies to find out how gliders fly without engines.

Stephen Ashby
In this issue, tech wizard Steve explains the inner workings of the new Xbox One S. He also reviews some of the latest knowledge book releases.



REGULARS

The LED-lit circuit poses a variety of challenging obstacles for the pilots to navigate through

The world's first indoor drone arena

A high-tech circuit built solely for drone practice has opened in South Korea

More and more people are piloting their own drones, which can cause problems in crowded cities. Luckily, Chinese company DJI has a solution, in the form of the first indoor drone arena. Based in the city of Yongin, South Korea, the futuristic-looking circuit welcomes both rookies and experienced UAV (unmanned aerial vehicle) pilots, as 12 drones at a time can enter the 1,395-square-metre arena.

South Korea has a thriving drone culture, and the centre will also educate budding drone enthusiasts on the fast-growing hobby. The DJI Arena is packed full of tech, and the innovative LED-lit circuit provides a tricky training course for pilots.

The circuit is kitted out with LCD screens that give a first-person view of the drone, as well as charging docks and an area to carry out repairs to any broken UAVs. There are even safety nets that will protect any drones that might head off course. For amateur flyers, there is a private training room where an experienced drone pilot is on hand to give one-to-one lessons. The drone used to teach children the basics of UAV handling is the Phantom 4, which boasts features like ActiveTrack, TapFly and obstacle avoidance.

The arena provides a safe environment where drones can be flown without fear of adverse weather conditions damaging the technology or causing a nuisance in public areas. Events currently range from individual bookings to a flying academy and school tours, and as more and more pilots use the DJI Arena, there will be scope for different flying experiences. There's even talk of the prospect of an indoor drone-racing track in the future.

"The arena provides a safe environment where drones can be flown without causing a nuisance in public areas"

Pilots can fly in the arena without fear of damaging their drones

Anti-drone eagles

Drones can be a threat to safety and security, so some countries are implementing innovative tactics to keep the skies UAV-free

As well as the eagles, the DNP are also using electromagnetic pulses to bring down drones from the sky

In a unique programme, the Dutch National Police (DNP) has imported and trained North American bald eagles to snatch troublesome UAVs from the sky. The new approach comes after a rise in the use of civilian drones and the birds of prey will be instructed to attack any that appear to represent a security threat. The eagles are trained to use their razor-sharp talons to attack the drones. Seeing it as prey, they first disable their target before taking it a safe distance away from crowds and buildings. There is some concern about the damage spinning propellers could do to the eagles themselves, so the birds have been given claw protectors that will prevent injury to the eagles' feet when in the line of duty. The DNP is the only police force in the world to have undertaken this unique anti-drone measure, but others may soon follow.

Earth's closest exoplanet is thought to be a rocky world that could have liquid water on its surface

How did they find it?

Proxima b was discovered when astronomers noticed a tiny back-and-forth wobble of the star Proxima Centauri. Using the ESO 3.6-metre telescope in Chile, they noticed that at times, the star would approach Earth at about five kilometres per hour, then recede at the same speed. This regular pattern of movement repeated every 11.2 days, and careful analysis showed it was caused by the gravitational pull of an orbiting planet. Now the focus is on getting a direct image of Proxima b and detecting if it has an atmosphere, which should be made possible by the next generation of telescopes that are currently in development.

The ESO 3.6-metre telescope in Chile detected a wobble of nearby star Proxima Centauri

CLOSEST EARTH-LIKE PLANET FOUND

Scientists discover our nearest habitable world outside the Solar System

An exciting new development in the search for alien life has been found right on our doorstep, although it's still a bit too far away to visit. The potentially habitable planet Proxima b has been discovered orbiting Proxima Centauri, our closest star after the Sun. However, while in space terms it's pretty close, it is still 4.3 light years (40 trillion kilometres) away, a distance it would take current spacecraft thousands of years to travel.

The planet is thought to be habitable because it lies within a Goldilocks zone, an area around a star where temperatures are not too hot or too cold for water to exist in liquid form. Proxima b is actually much closer to its host star than Earth is to the Sun. However, Proxima Centauri is a red dwarf star, smaller and dimmer than our own Sun, and therefore provides the exoplanet with similar conditions to Earth despite its proximity.

Before we get excited about meeting little green men or other forms of alien life though, there's a potential problem. Scientists do not yet know if Proxima b has an atmosphere, which would be important for retaining the heat and pressure for liquid water to exist, and is also needed to protect any potential inhabitants from the high energy radiation blasting from its highly active host star.

There's also the fact that we won't be stepping foot on Proxima b any time soon, although Russian entrepreneur Yuri Milner and physicist Stephen Hawking are working on it. Their Breakthrough Starshot initiative has been set up to develop unmanned light-propelled nanocraft capable of reaching Alpha Centauri, the star system to which Proxima Centauri belongs, in a matter of decades.

NEWS BY NUMBERS

172

The days spent on board the ISS by the three Expedition 48 astronauts who returned to Earth on 7 September

1%

The oxygen demands of a fat-tailed dwarf lemur drop to 1 per cent of their usual levels while hibernating

50

The number of teams taking part in the first Cybathlon, or 'bionic Olympics', this October

3 min 48.29 sec

The new 1,500m Paralympic world record set by Algeria's Abdellatif Baka at Rio 2016. It was 1.7 seconds faster than the Olympic record!

The Tesla Model S P100D is also the longest-range production electric vehicle

Tesla gets quicker

The new electric Model S is the fastest accelerating production car ever produced

Although it technically falls behind the LaFerrari and Porsche 918 Spyder when competing for the quickest production car title, the new Model S P100D is the only one of the three that can be bought new, and won't cost you a million dollars. Therefore, Tesla is claiming the top spot for its pure electric, all-wheel drive seven seater. When switched to 'Ludicrous' mode, a battery pack and electronics upgrade that boosts the car's power, it can go from zero to 97 kilometres per hour in 2.5 seconds.

Lucy's fall may lend support to the theory that ancient humans spent a lot of time in trees

Lucy fell from a tree

The mystery surrounding our famous ancestor's death has been solved

Lucy, the name given to the oldest and most complete skeleton of an erect-walking, adult human ancestor ever found, most likely died after falling from a great height. Researchers studying the fossil have found a fracture in the right arm that typically occurs when someone reaches out to break a high velocity fall from a height of more than 12 metres. This has led them to believe that Lucy probably fell while foraging or seeking refuge in a tall tree.

Dogs understand human speech

The canine brain can register what you say, not just the way you say it

If you tell a dog to 'sit', you might think they're just responding to the intonation, or pitch, of your voice, but a new study has revealed the truth. Scientists played dogs recordings of their trainers' voices using multiple combinations of vocabulary and intonation for both praising and neutral commands, then analysed their brain activity using an fMRI machine. Not only did they find that the animals processed each word regardless of intonation, but they did so using the same brain regions as humans.

10 COOL THINGS WE LEARNED THIS MONTH

Cockroach milk could be a new 'superfood'

Imagine you're in need of some high-calorie, nutritious milk, and rather than heading straight for the dairy aisle, you opt for the cockroach milk variant instead. This bizarre scenario could soon be commonplace, as researchers in India have found that a formula produced by the Pacific beetle cockroach – which it uses to feed its unborn young – is rich with a unique protein that makes it four times as nutritious as dairy milk.

Tasmanian devils are evolving at super speed

A fatal cancerous disease has swept through Tasmanian devils, wiping out approximately 80 per cent of the population. This intense selection pressure has meant that the remaining population rapidly evolved, and their genomes, the complete set of genes or genetic material present in the organisms, are now distinctly different from their ancestors from just 20 years ago. Genetic changes in two regions – thought to be associated with cancer and the immune response – have allowed the devils to fight back against this deadly threat to their existence.

Otherworldly signal may not be from aliens

Russian scientists revealed a 'strong signal' that was received by the RATAN-600 radio telescope. Its source was an alien world 95 light years away – or so we thought. Astronomers have asserted that unrealistic amounts of power would be required for a signal to reach Earth from that distance, and a spark from a power line could have interfered with the telescope.

A Mars simulation kept scientists isolated for a year

Six people have emerged after a year of confinement on a Hawaiian volcano. In order to simulate the conditions of a life on Mars, the crew were only permitted to explore the Red Planet-like terrain in spacesuits, and spent the rest of their time inside a solar-powered dome with restricted internet access and a diet heavily reliant on dehydrated and canned foods.

British scientists solved the global chocolate crisis

Production of cocoa is on the decline. But researchers from Bangor University have announced that mango butter has similar chemical, physical and thermal properties to cocoa butter, and could be used as a replacement. Due to its higher moisture content, the alternative could even produce lower-fat chocolate.

We can make ice cream that doesn't melt

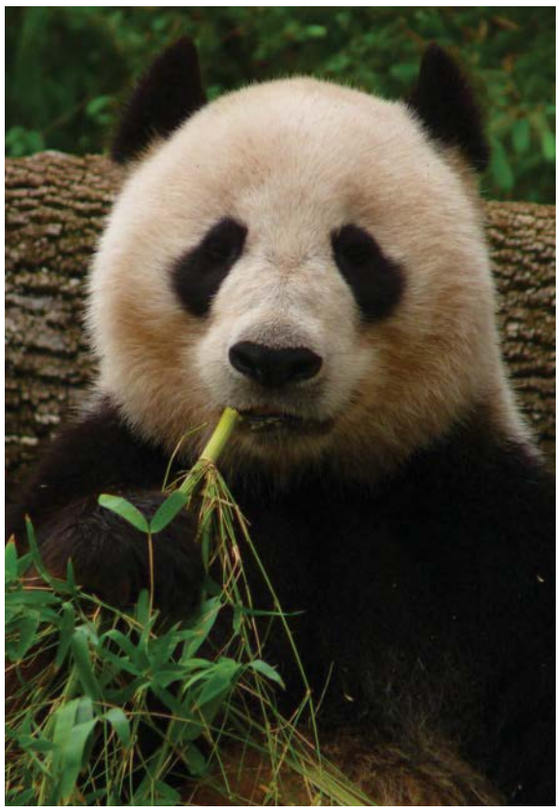
Racing to finish a melting ice cream is a problem that may soon be behind us. By adding a protein that is found in a Japanese fermented soybean dish known as 'natto', which binds together the fat, water and air in the ice cream, Scottish scientists have found a way to keep the frozen treat solid for longer.

Crystal gardens could lead us to the origins of life

Hydrothermal vents on the sea floor allow life to flourish, even at depths where light cannot penetrate. Chemical imbalances around these vents cause minerals to build up into a 'garden' of crystal structures, that may have played a role in the origin of life on Earth – and perhaps on other planets, too. Scientists have re-created miniature crystal gardens in glass jars to observe how this process could have unfolded.

A 'blue whirl' fire tornado could clean up oil spills

Fire tornados are spawned when a flame is caught in a whirling column of air, and are capable of devastating destruction. The 'blue whirl' appears when the flames are able to react with enough oxygen to combust completely, meaning they don't produce any soot. This could be used to help clear oil spills, by burning away the layer of oil cleanly and efficiently.



Giant pandas are no longer endangered

The number of giant pandas in the wild has now surpassed 2,000, thanks to conservation efforts in their homeland of China. This has led their status to be downgraded from 'endangered' to 'vulnerable'. By banning poaching, protecting forests and introducing new reforestation measures, the panda's habitat is now a larger and safer place.

Finches quench thirst with their own fat

Zebra finches are native to the hot climates of Australia, and are the first birds shown to be able to break down fat cells to keep themselves hydrated when deprived of water, allowing them to preserve precious muscle tissue.

ARMED & DANGEROUS ATTACK HELICOPTERS

THE DEADLY GUNSHIPS ELIMINATING THE ENEMY FROM ABOVE

The AH-64 Apache is one of the most iconic and successful attack helicopters

"Many new gunships were constructed as the Cold War escalated"

The V-280 Valor will attempt to make attack helicopters faster and stronger than ever before

The modern attack helicopter is the complete military machine. Cutting through the air with titanium blades, loaded up with missiles and a cockpit full of advanced technology; they are true terrors of the sky. A tank's worst nightmare, the rise of attack helicopters has revolutionised the battlefield.

The idea of rotary wing military aircraft was first toyed with during the early years of World War II but it wasn't until 1942 that they reached prominence. That year the US War Department proposed a new idea. It was called 'organic Army aviation' and, separate from the Air Corps, it was tasked with developing helicopters. Various new designs, including the revolutionary Sikorsky R-4, were created but it took until the Korean War for helicopters to really take off. Infantry and cargo could now be ferried in and out of battle rapidly and invasion forces could engage the enemy much more effectively from the air. Helicopters were integral to US operations in the rough terrain of Korea and by the time of the Vietnam War, the iconic Bell UH-1 Iroquois was used extensively. The 'Huey' ushered in a new era of air cavalry, as helicopter weaponry became more sophisticated.

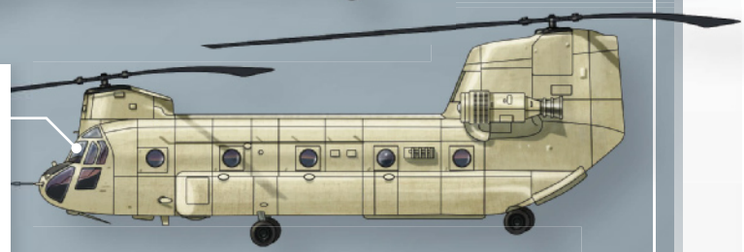
Military helicopters were also designed to serve in a purely offensive capacity and the attack helicopter was born. Many new gunships were constructed as the Cold War escalated. These included the American Piasecki H-21 and Bell AH-1 Cobra and the Russian Mil Mi-24. In 1986, the Boeing AH-64 Apache emerged as a template that other armed forces tried to replicate, and helped bring an end to the dominance of tanks on the battlefield. As more breeds of attack helicopter took to the skies, it became clear that these versatile vehicles could assist the military in many ways. This led to the advent of dual and multi-role helicopters.

In recent years, attack helicopters have been equipped with ever more advanced systems that have improved efficiency, aerodynamics and performance. The array of tech on offer is truly astonishing, but there is still room for further progress. Join us as we examine what's on offer for the future of the world's best attack choppers.

TYPES OF MILITARY HELICOPTER

Choppers are an essential part of modern warfare, from reconnaissance to attack

Attack
Commonly known as gunships, attack helicopters come armed with a multitude of rockets, missiles and chain guns. The AH-64 Apache specialises in disabling tanks.



Transport
Supplies and troops can be quickly whisked in and out of war zones. A popular design is the CH-47 Chinook which has a primary role in heavy troop and supply transport.

Multi-role
State-of-the-art navigation and communication systems allow helicopters to assist almost any mission. Their roles range from observation to search and rescue.

Maritime
Maritime helicopters provide invaluable aerial support out at sea. The Sikorsky SH-60 Seahawk takes off from aircraft carriers and frigates and can take down submarines with its MK 54 torpedoes.

Scout
Helicopters like the Aérospatiale Gazelle are used to investigate unknown terrain. They are sent ahead of the front line to inspect what lies in wait for the ground forces.

THE TIGER

The all-action attack gunship that is a key player in modern aerial warfare

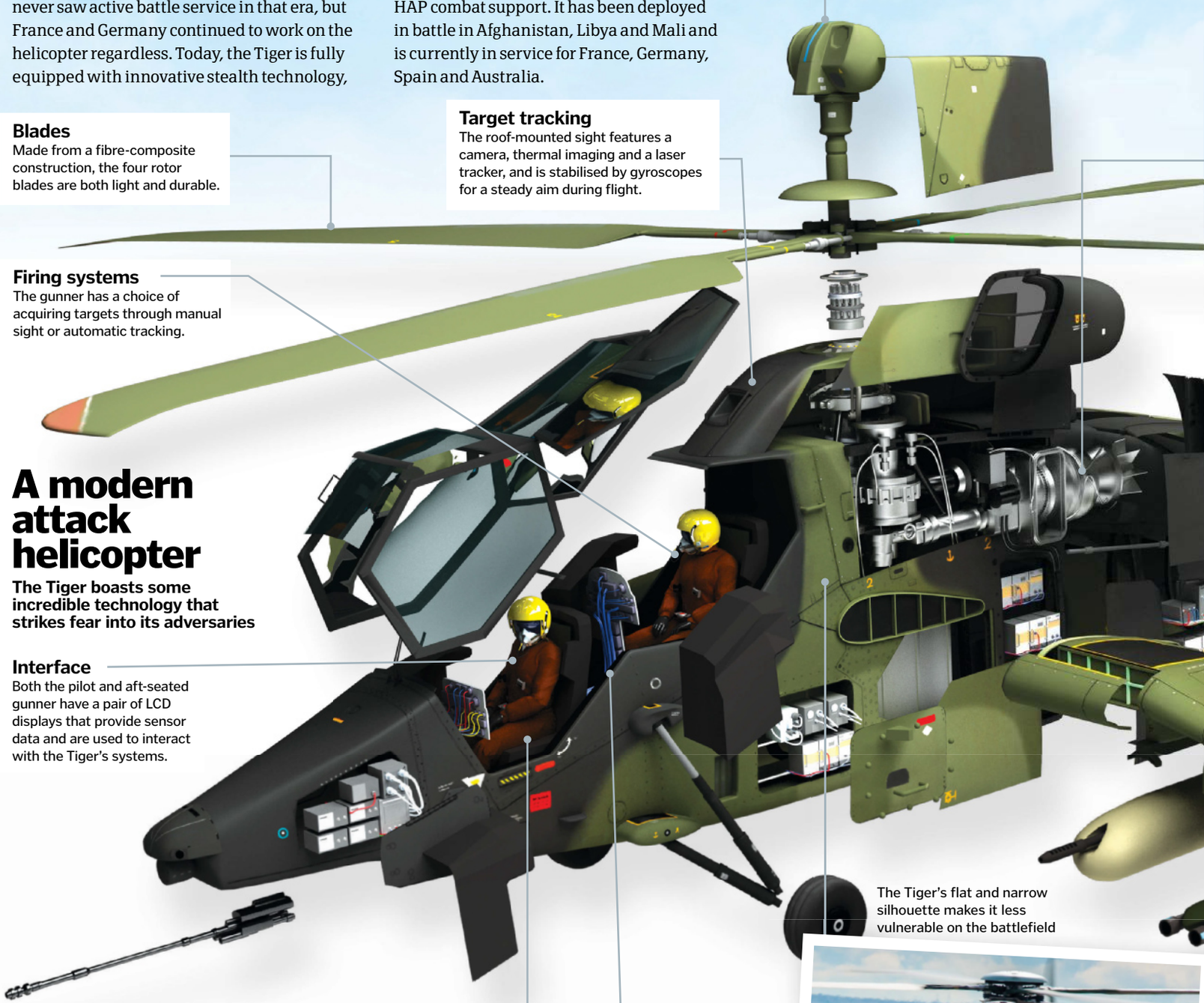
A heavy-hitting, relentless attack dog, the Airbus Helicopters Tiger has both the armament and performance capabilities to dominate the battlefield. During the Cold War, it was developed in order to respond to any potential attacks on Western Europe by the USSR. The subsequent collapse of the Soviet Union meant it never saw active battle service in that era, but France and Germany continued to work on the helicopter regardless. Today, the Tiger is fully equipped with innovative stealth technology, highly accurate GPS systems, and electronic countermeasures. It specialises in anti-tank missions but the Tiger's flexibility means that it can handle a variety of roles. The image below is of an HAD combat helicopter but other models include the UHT multi-role fire support, ARH Armed Reconnaissance and HAP combat support. It has been deployed in battle in Afghanistan, Libya and Mali and is currently in service for France, Germany, Spain and Australia.

Mast-mounted sight
Electronics company SAGEM supply the Osiris sight that acts as a forward looking infrared (FLIR) camera and laser rangefinder.

Blades
Made from a fibre-composite construction, the four rotor blades are both light and durable.

Target tracking
The roof-mounted sight features a camera, thermal imaging and a laser tracker, and is stabilised by gyroscopes for a steady aim during flight.

Firing systems
The gunner has a choice of acquiring targets through manual sight or automatic tracking.



A modern attack helicopter

The Tiger boasts some incredible technology that strikes fear into its adversaries

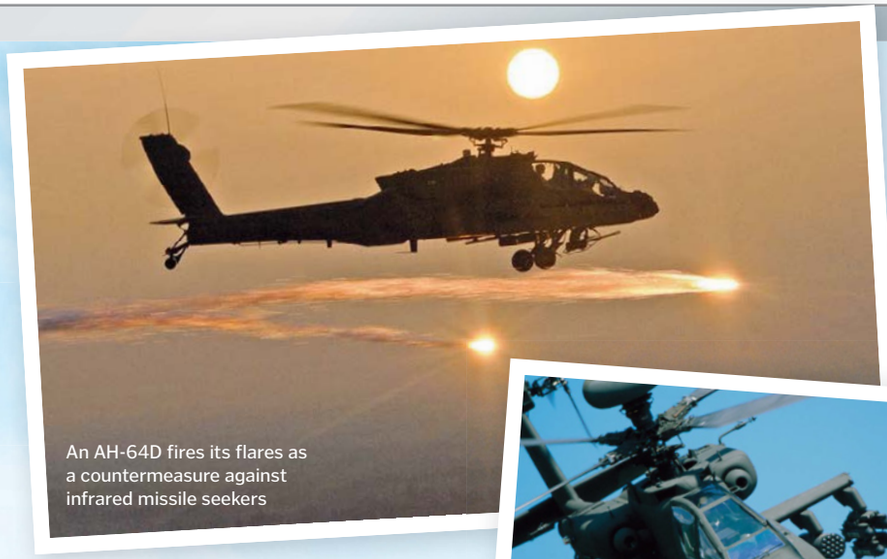
Interface
Both the pilot and aft-seated gunner have a pair of LCD displays that provide sensor data and are used to interact with the Tiger's systems.

"The fuel tanks are self-sealing and explosion suppressive"

Advanced cockpit
The pilot is assisted by an automatic flight control system that lessens the workload during long, strenuous flights and adverse weather conditions.

Cockpit
The Tiger's tandem cockpit allows the pilot and the aft-seat gunner to switch roles if needed, as both have access to the flight controls and weapon systems.

The Tiger's flat and narrow silhouette makes it less vulnerable on the battlefield



An AH-64D fires its flares as a countermeasure against infrared missile seekers

AH-64D APACHE LONGBOW

An iconic gunship that's still a capable attack chopper

The AH-64D Apache Longbow gunship is arguably the most famous multi-mission attack helicopter of the modern age. Over the past 19 years of service, it has proven itself both combat-ready and reliable in numerous theatres of conflict.

The AH-64D was upgraded in 2008 to include increased digitisation, a joint tactical radio system, enhanced engines and drive systems, the capability to control UAVs (unmanned aerial vehicles) – which were used extensively in the Iraq and Afghanistan wars – along with improved landing gear. Currently, the Apache AH-64D Longbow is operated by the US, Egypt, Greece, Israel, Japan, Kuwait, the Netherlands, China, Singapore and the United Arab Emirates, with many other countries operating older Apache variants.

Power
The Tiger is powered by two 960kW turboshaft engines. The fuel tanks are self-sealing and explosion suppressive when exposed to enemy fire or in the event of a crash.

Fuselage
Kevlar, carbon laminates and Nomex make up 80 per cent of the airframe, and radar reflective surfaces are kept to a minimum.

Mistral missiles
With a 3kg warhead and a 6km range, the Tiger can cause significant air-to-air damage over long distances.

Weaponry
The Tiger can be fitted with different combinations of weapons depending on the variant, suitable for both air-to-ground and air-to-air combat.

1. T700-GE-701C engines
The turboshaft engines allow the AH-64D Longbow to reach a cruise speed of 284km/h.

2. Automatic cannon
The 30mm automatic cannon is capable of firing large, highly incendiary rounds.

3. Hellfire missiles
These laser-guided missiles are effective at taking down enemy armour and structures.

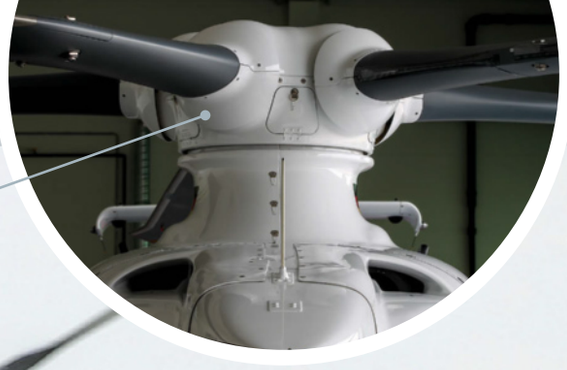
4. Explosive rockets
Fast firing 70mm rockets allow the Apache to support ground troops in any assault on enemy soldiers, strongholds or vehicles.

5. Cockpit
With room for two, the Apache's cockpit allows excellent battlefield visibility with wide viewing angles.

6. Composite rotor blades
A composite four-blade main rotor allows for increased payload, climb rate and cruise speed over earlier variants.

7. Fuselage
Designed for manoeuvrability and stealth, the fuselage is painted in camouflaged colours.

8. Radar dome
This system enables target detection from behind obstacles.



The Bluecopter

Introducing Airbus' eco-efficient demonstrator – a game-changer that could make choppers more stealthy

Blue Edge technology
The five Bluecopter blades decrease noise pollution without affecting performance.

Reduced emissions
CO_2 emissions and fuel consumption are decreased by up to 40 and 10 per cent respectively.

Rudder
The T-tail stabilises the vehicle, decreasing the tendency for the nose to rise up.

Blue Pulse tech
Active flap rotor control reduces the interference of the blades with each other, reducing noise levels.

Tail rotor
The Fenestron is a tail rotor housed in an insulated duct to reduce drag and noise.

Eco-mode
One of the Bluecopter's engines can be temporarily shut down to decrease emissions.

Aft-body concept
The design of the back of the helicopter helps make it more aerodynamic.

Skids
A specially made fairing on the skids lowers the Bluecopter's drag.

The Bluecopter has allowed Airbus to test innovative, eco-friendly technologies

STEALTH HELICOPTERS

How tech can help make choppers a whole lot quieter

One of a military helicopter's biggest strengths is its manoeuvrability. Being able to take off and land in difficult terrain, move in any direction and hover makes gunships incredibly useful in battle. However, this advantage comes at a price and the sound of the rotor blades spinning almost negates any chance of a stealthy approach. Helicopter blades are noisy because of blade-vortex interaction (BVI). Each blade rotates at such a speed that high amounts of turbulence are caused. Huge amounts of air flow around the blades as they turn and a concentrated vortex (a whirling mass of air similar to a whirlwind) is formed. As each following blade cuts through this vortex, acoustic energy and vibrations are created, resulting in the classic chopper sound. It has been a long-standing issue but now various technologies are being implemented in an attempt to reduce it.

Airbus' Bluecopter has a new style of rotor blade that utilises Blue Edge technology. The innovative double-swept design reduces noise by four decibels by reducing the surface area of the blade that impacts on the vortex. This is complemented by Blue Pulse technology, which incorporates three flap modules into every blade. Directed by a flap rotor control that uses tiny electric motors powered by crystals, they move at up to 40 times a second, lessening the BVI as less pressure is created. This decreases the level of noise generated, as well as giving the pilot a smoother ride with a significant reduction in cabin vibrations.

Another method the Bluecopter is using to make it both greener and stealthier is a Fenestron. This encases the tail rotor and allows the mechanism to have more blades, which adds more thrust, while reducing drag and vibration. On the Bluecopter, stealth technology is used in conjunction with aerodynamic landing skid fairings and a T-tail stabilising rudder to increase efficiency and decrease emissions.

"The innovative double swept design reduces noise by up to four decibels"

Operation Neptune Spear

On 1 May 2011, US President Barack Obama declared to the world that Osama bin Laden had been killed. The operation that disposed of the founder of Al-Qaeda was codenamed Operation Neptune Spear and was undertaken in two Black Hawk helicopters supported by two MH-47 Chinooks. During the mission, one of the Black Hawks ran into difficulty and had to make a hard landing. It was reported that before leaving, the SEALs made efforts to destroy the downed chopper, leading aviation analysts to believe they were equipped with secret stealth technology. US authorities have remained tight-lipped on the matter, but photos of the surviving wreckage appeared to show modifications to the tail section to suppress noise and avoid radar.

The UH-60 Black Hawk has become the US Army's premier multi-role helicopter

TYPES OF MILITARY HELICOPTER MISSIONS

Powerful, agile and resilient, the Tiger is the chopper of choice in many situations

Ground fire support

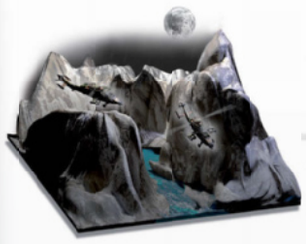
Infantry and armoured divisions on the ground can rely on the Tiger to provide backup. The 30mm gun is incredibly accurate and can fire at a maximum distance of 2,000m.

Amphibious operations

The Tiger HAD is also a worthy adversary at sea. It was designed to be able to land on aircraft and its low maintenance requirements mean it can stay out at sea for long periods.

Escort

Operations in Afghanistan, Libya and Mali allowed the Tiger to display its prowess as an escort chopper. It can easily eliminate threats and guide others to safety.



Armed reconnaissance

Day and night identification sensors make the Tiger a highly competent reconnaissance unit that can weave through tough terrain and also engage the enemy if it needs to.

Aerial combat

The twin attack power of a 30mm turreted gun and Mistral missiles are more than a match for any other helicopter. Also on board are 32 chaff and flare cartridges.

Anti-tank warfare

The range of powerful anti-tank missiles at the Tiger's disposal make it the ideal gunship. It can take out tanks from a safe distance, firing from up to 8,000m away.

Ask the expert

We spoke to Marius Bebesel, programme manager at Airbus to explain more about the Bluecopter

What sort of helicopter is the Blucopter?
Based on an H135, the Bluecopter technology demonstrator is a light, twin-engine helicopter. It is a flying technology test bed, on which Airbus Helicopters is able to trial next-generation eco-friendly technologies that can be applied across Airbus Helicopters' product line. The Blucopter is a unique, one-of-a-kind, test aircraft.

How environmentally friendly and energy efficient is it?
The Bluecopter allowed Airbus Helicopters to test performance and fuel management technologies (including an 'eco-mode', which shuts down one of the two engines during standard cruise) leading to a ten per cent reduction in fuel consumption, helping to achieve a 40 per cent CO_2 emissions reduction.

The demonstrator features several design measures to reduce the aerodynamic drag of the helicopter. This includes fairings for the main rotor hub and the landing skids, and a newly developed low drag aft-body concept.

The eco-friendly approach is extended even to the attractive paint scheme of the helicopter, which makes use of the latest water-based paint technologies.

Do you have plans for any electric helicopters?
Airbus Helicopters is researching lower emissions technology with its compound helicopter LifeRCraft and the High Compression Engine (using an advanced diesel engine instead of a turbine for light helicopters).

Airbus Group has teamed up with Siemens to research electric flight. It is thought that by 2030 passenger aircraft below 100 seats could be propelled by hybrid propulsion systems.

V-280 Valor

The innovative new Bell and Lockheed Martin design that boasts unrivalled speed, range and payload capabilities

VTOL technology
The advanced tilt-rotor technology will allow for vertical lift-offs from almost any terrain.

Tilt-rotor
The counter-rotating dual propellers enable great manoeuvrability.

Sensor technology
Enhanced situational awareness systems ensure bombing during missions is incredibly precise.

Capacity
The large armoured fuselage can fit 14 troops and four crew members.

Speed and endurance
The top speed will be over 500km/h with a combat range of nearly 1,500km.

Rotor downwash
Decreased downwash from the rotor blades makes rope hoist operations easier and safer.

The innovative technologies used on the Raider allow it to reach much higher speeds than standard choppers

MILITARY HELICOPTERS: THE NEXT GENERATION

What does the future have in store for a new class of supercopter?

While the Boeing AH-64 Apache and the Sikorsky UH-60 Black Hawk are still capable gunships, even more advanced updates are on the horizon. Both companies are at the forefront of future helicopter design and are aiming to develop choppers that will boast twice the speed and twice the range of the current crop. The two aviation giants are currently joining forces to create the SB>1 Defiant while Bell and Lockheed has its own rival project in the shape of the V-280 Valor. Both ventures are demonstrator aircraft and will act as trial runs to potential future helicopter designs under the Future Vertical Lift (FVL) project. They will take to the skies for testing as part of the US Army's Joint Multi-Role programme in early 2017. FVL includes five all-new helicopters that will replace the current designs with a new breed of attack copter. As well as having first-class combat capabilities, the new helicopters will embrace semi-autonomous technology and be flexible enough to serve in urban security, disaster relief and medical evacuation. Each of the aircraft will use a new active system that will advise the crew on when components in the cockpit need to be replaced, while also giving as much assistance as possible to the pilot. Compatibility with other vehicles will be at the forefront of the new choppers' design. They will be capable of landing on ships and being stored on cargo planes. These ultra-advanced helicopters are set to be in production by 2030 and will serve the US Army, Navy, Air Force and Marine Corps.

"The new helicopters will embrace semi-autonomous technology"

As well as attack helicopters, the classic Chinook design will also be getting an overhaul.

SB>1 Defiant

Sikorsky and Boeing's joint venture could help change the face of helicopter technology

Coaxial rotors
The double counter-rotating rotors are immensely powerful yet agile enough to land on aircraft carriers.

Full of fuel
The large fuel tanks have been designed to hold enough to fuel a powerful future engine.

Pusher propeller
The pusher propeller will allow top speeds of over 450km/h even in adverse weather conditions.

Autonomous assistance
Fly-by-wire technology will kick in and take the chopper to safety if the pilot is injured.

Defence mechanism
A high-tech laser jammer is installed to divert the path of any missiles targeting the SB>1 Defiant.

Advanced cockpit
The pilot will be assisted by cognitive decision-aiding technology that prioritises the flow of navigational information.

Spacious fuselage
The chopper weighs over 13 tons and can transport 12 soldiers and a crew of four.

The Block II Chinook programme will see Boeing's iconic twin rotor vehicles undergo a modernisation project. They will still utilise the same basic design but will be kitted out with an assortment of modern technology. All the projects are a fascinating glimpse into the future and will build on the already cutting-edge technology used in today's helicopters. While drones continue their vital role on the front line of aerial combat, the attack helicopter will once again dominate the skies with more advanced engineering and weaponry than ever before.

The Raider's cockpit can fit two pilots and the cabin will have space for six soldiers

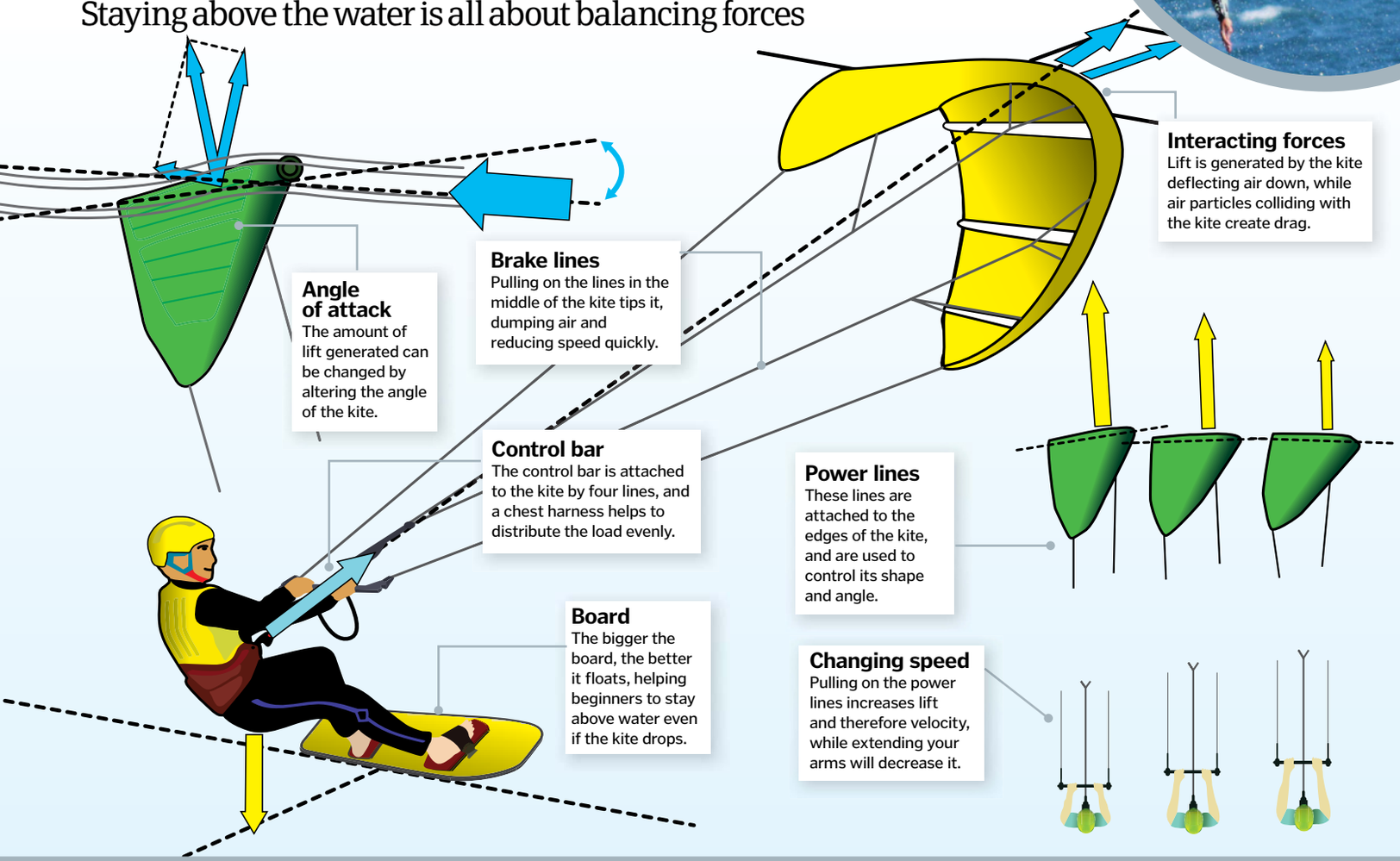
S-97 Raider

Sikorsky is currently developing a new generation of helicopter. Utilising innovative technology, the S-97 Raider has not one but two coaxial counter-rotating rotors. These rotors are mounted on the same shaft but rotate in opposite directions. This advanced rotor-wing technology will be accompanied by a push propeller at the rear and will enable the vehicle to reach altitudes of 3,000 metres even in the most challenging climates, travelling at twice the speed of the fastest helicopters currently in the air. As well as its superior performance, the Raider is designed to have a reduced turning radius and lower sound emissions than current helicopters. Its likely role within the military will be as a light tactical vehicle but it still packs a punch and comes equipped with Hellfire missiles. The Raider will be equally adept at armed reconnaissance and search and rescue missions and comes complete with retractable landing gear, vibration control and thermal management systems for this purpose.

The Raider conducted its maiden flight in 2015 and is currently still under development

Kitesurfing physics

Staying above the water is all about balancing forces



Angle of attack
The amount of lift generated can be changed by altering the angle of the kite.

Brake lines
Pulling on the lines in the middle of the kite tips it, dumping air and reducing speed quickly.

Interacting forces
Lift is generated by the kite deflecting air down, while air particles colliding with the kite create drag.

Control bar
The control bar is attached to the kite by four lines, and a chest harness helps to distribute the load evenly.

Power lines
These lines are attached to the edges of the kite, and are used to control its shape and angle.

Board
The bigger the board, the better it floats, helping beginners to stay above water even if the kite drops.

Changing speed
Pulling on the power lines increases lift and therefore velocity, while extending your arms will decrease it.

How do electric unicycles work?

Discover the tech behind these self-righting gadgets

Electric unicycles are famously self-balancing, so riders can accelerate simply by leaning forward, or decelerate by leaning backwards. This intuitive steering system depends on a combination of technologies in order to work properly. First, the batteries are connected to an electric motor made up of numerous wire coils. When an electric current runs through the motor, these coils constantly repel a series of magnets on the wheel rim, allowing the wheel to spin smoothly.

The key component is the gyroscope, which senses when the unicycle changes orientation. In a way, it's like an electronic version of a spirit level, in which a bubble of air moves as the level is rotated. A magnetic sensor works with the gyroscope to detect the direction of travel and the wheel's rotational speed, and everything in the system is connected to a powerful central processing unit (CPU).

The gyroscope continuously measures the wheel orientation, and feeds that information back to the CPU. Leaning forward sends the instruction to deliver more power to the motor, speeding the unicycle up, in an attempt to 'catch up' with the rider. Leaning back decreases the power delivered to the motor, reducing the speed.

It takes a lot of practice to get used to riding electric unicycles!

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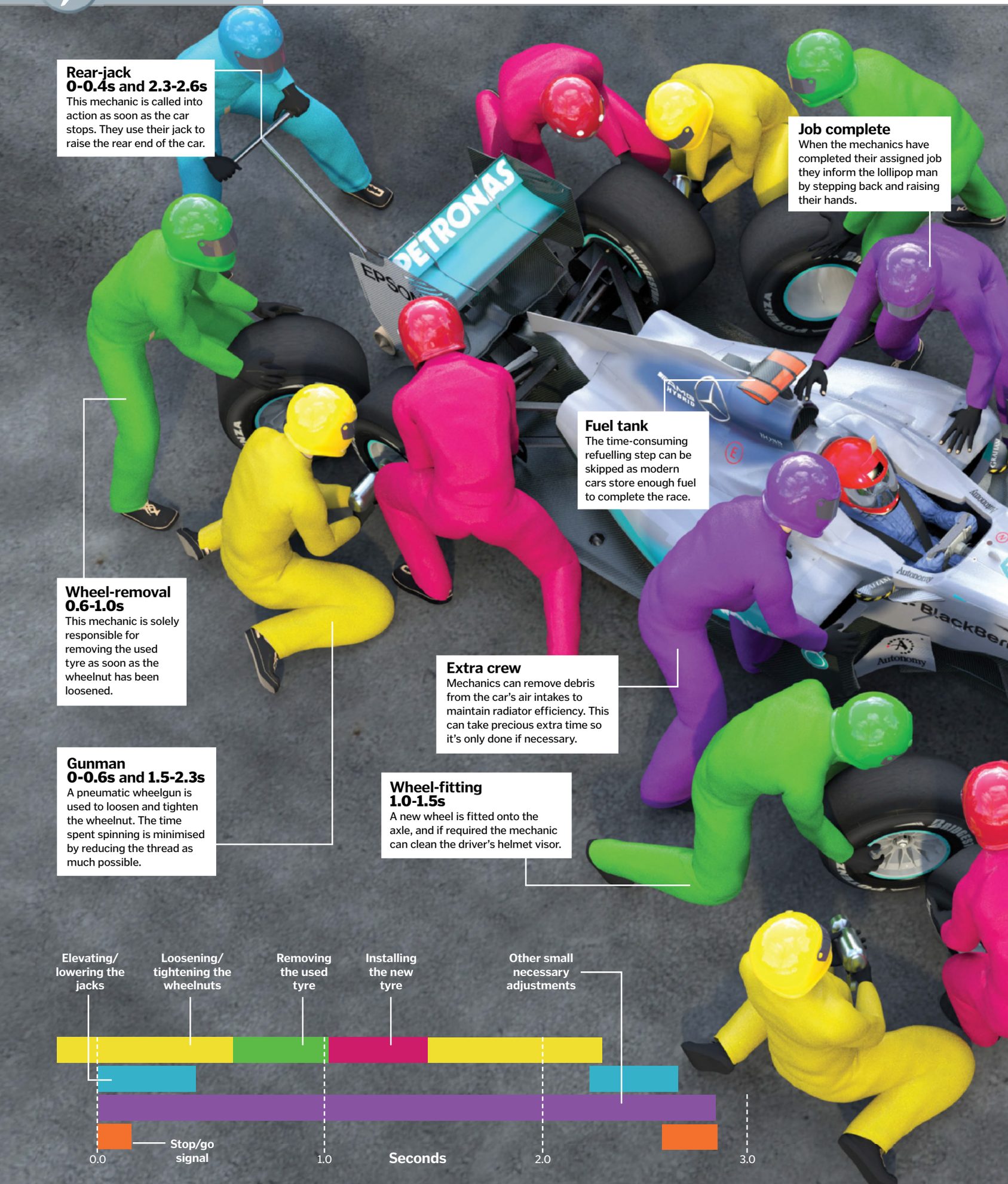


Rear-jack
0-0.4s and 2.3-2.6s
This mechanic is called into action as soon as the car stops. They use their jack to raise the rear end of the car.

Job complete
When the mechanics have completed their assigned job they inform the lollipop man by stepping back and raising their hands.

Fuel tank
The time-consuming refuelling step can be skipped as modern cars store enough fuel to complete the race.

Wheel-removal
0.6-1.0s
This mechanic is solely responsible for removing the used tyre as soon as the wheelnut has been loosened.

Extra crew
Mechanics can remove debris from the car's air intakes to maintain radiator efficiency. This can take precious extra time so it's only done if necessary.

Gunman
0-0.6s and 1.5-2.3s
A pneumatic wheelgun is used to loosen and tighten the wheelnut. The time spent spinning is minimised by reducing the thread as much possible.

Wheel-fitting
1.0-1.5s
A new wheel is fitted onto the axle, and if required the mechanic can clean the driver's helmet visor.

Pit stops

How highly-trained experts perform engineering miracles at every race

In Formula One racing, every second counts. The incredibly powerful cars are built for speed, able to drive in excess of 360 kilometres per hour, but they need constant maintenance to complete a race. Fortunately, the driver's team of mechanics are ready and waiting in the pit lane to restore the car to an optimal condition in lightning-fast time.

Before the car even pulls to a stop, the pit crews get to work on changing tyres, clearing debris and adjusting or exchanging parts of the vehicle.

By following a precise, rehearsed routine, Formula One teams are able to complete their work in less than three seconds on average. And considering winners have been decided by differences of under a fifth of a second, the best pit crew can be the difference a champion needs.

Firefighter
A crew with firefighting equipment are always ready in case of an emergency.

Lollipop man
0-0.1s and 2.6-2.8s
This team member is named after the long 'stop/go' sign which they use to signal to the driver.

Adjustment crew
Team members are on hand to alter the angle of the wings, in order to increase or decrease downward force.

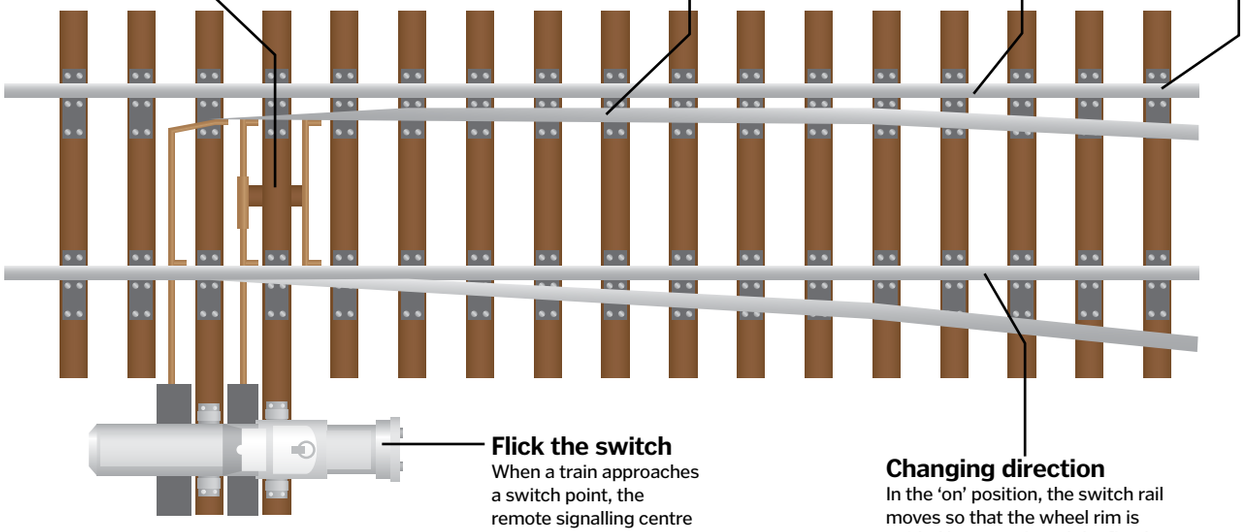
Front-jack
0-0.4s and 2.3-2.6s
The jack is placed under the nose of the car to raise it several centimetres above the ground.

Exploiting pit stop efficiency

Through watching the pit crew, the world has witnessed the benefits of detailed methodical planning and action. And now the healthcare and pharmaceutical industries are hoping to achieve the same levels of excellence by consulting with the Formula One teams. McLaren has helped drug manufacturer GlaxoSmithKline to switch production of toothpaste flavours in less than half of the original time, and the Williams team have advised doctors on improving their practice of resuscitating newborn babies. The University Hospital of Wales reorganised their equipment and created a floorplan with staff members assigned to specific places, and saw significant improvements as a result.

How do trains change tracks?

The simple switches that let trains reach different destinations



Switch motor
The motor is usually hydraulically or electromagnetically powered. It moves the switch to the correct position and holds it there as the train passes over.

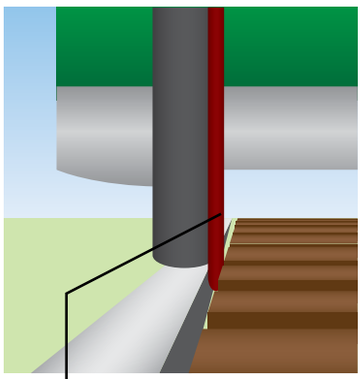
Changing tracks
The switch point is made from two tapered rails that are moved between intersecting train lines.

Straight ahead
In the 'off' position, the switch rail is positioned so that the wheels can move straight ahead, on the 'mainline'.

Smooth journey
Trains can safely switch between two tracks without having to slow down or stop.

Flick the switch
When a train approaches a switch point, the remote signalling centre sends a message to a motor at the point.

Changing direction
In the 'on' position, the switch rail moves so that the wheel rim is guided between it and the fixed rail, diverting it off the mainline.



Wheel guides
Train wheels have an inner rim that is larger than the rest of the wheel. It sits inside the rail and helps it change direction.

Why do car engines stall?

Cars mostly stall due to driver error, but it can also be caused by a mechanical or electrical failure

How a small slip-up can cause the engine to cut out

Even when a car is idling at traffic lights, its engine is still working hard. The crankshaft will be turning between 600 and 1,000 times every minute (that's 600 to 1,000 RPM), just to keep the engine running. If the RPM drops below this for any reason, and the engine stops, the car is said to have stalled.

Cars often stall when the clutch is engaged too quickly when setting off from a stop. The clutch is made of two metal plates, which connect the engine to the wheels. When you push the clutch pedal down, you disconnect these plates so that the engine can keep turning while the wheels stop, allowing you to stand still in traffic, for instance. If you release the clutch pedal and connect the plates when the RPM is too low, the engine will suddenly have a huge load placed on it that will stop it from moving, causing the RPM to drop and the engine to cut out. Instead, as you set off you need to bring the clutch up slowly, while increasing the RPM with the accelerator. This allows the force of the motor to increase in proportion with the load being placed on it, and the car will get going smoothly.

How do gliders stay airborne?

These engine-free vehicles have more in common with paper planes than you might expect...

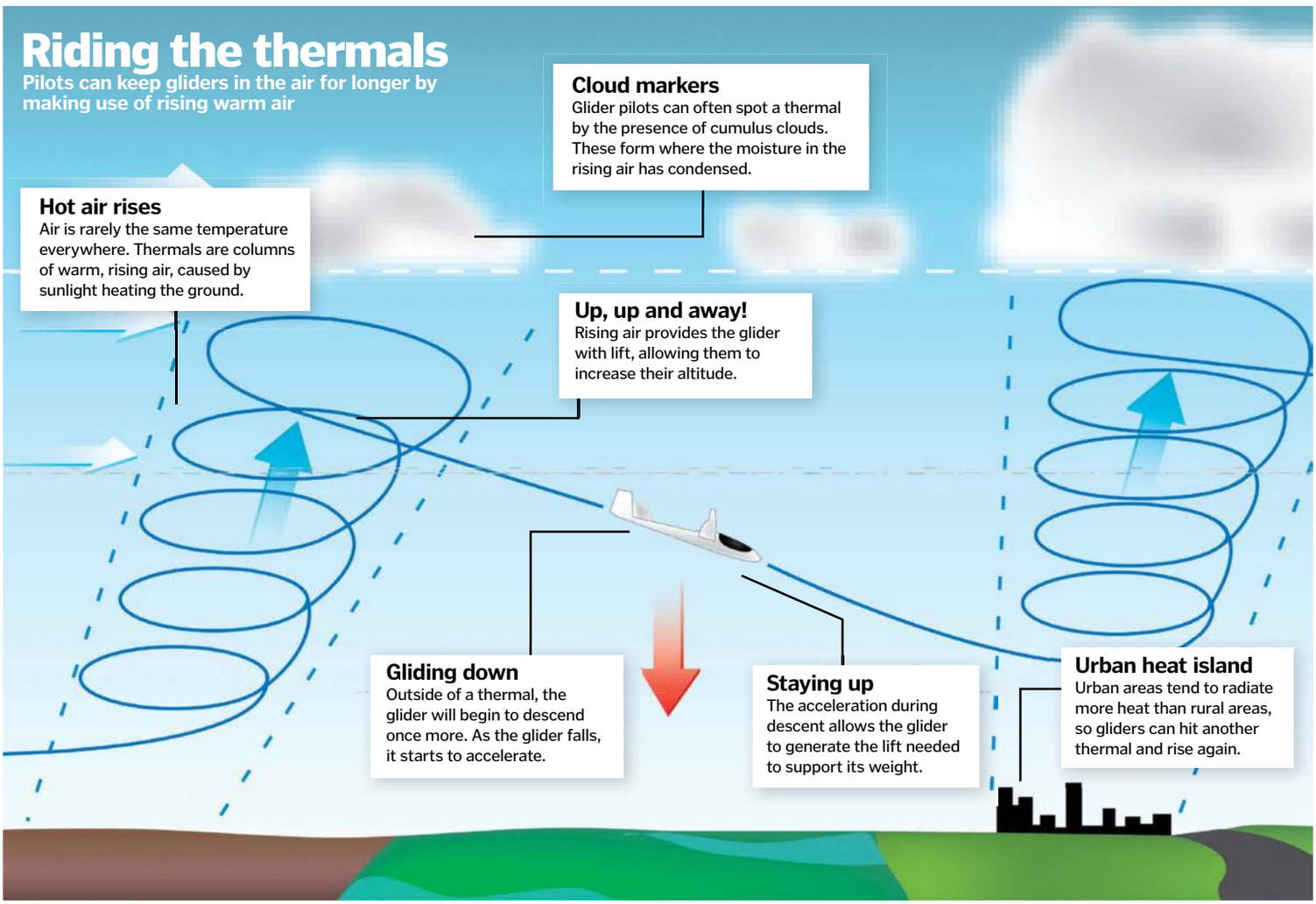
In its basic form, a glider is an aircraft with no engine, so they fly differently from powered aircraft due to the forces involved. When flying, a powered aircraft has four forces acting on it: lift, drag, weight (related to gravity) and thrust. Without an engine, gliders have no thrust, so they need to find other ways to generate speed. Key to this are a glider's wings – because they are so long, they generate huge amounts of lift, more than enough to help counteract the effect of gravity.

The glider needs some help to get into the air, though. There are two common ways to launch: either by towing it behind a powered plane as it takes off, before releasing it at altitude, or by rapidly winching along by a cable attached to a heavy-duty road vehicle. Once the glider gets up to speed, the wings come into their own, and the aircraft can take off. Alternatively, hang-glider pilots can run and jump off a hill or cliff to start their flight.

Really, the process of gliding is a very, very slow fall towards the ground. The speed of that descent is defined by its glide ratio, which tells you how far a glider can fly versus how much its altitude will drop. Hang-gliders have a glide ratio of around 15, which means that they can fly forward for 15 kilometres for every one kilometre of lost height. Commercial gliders, sometimes called sailplanes, descend much more slowly than hang-gliders – in fact, their glide ratios can be as high as 60.

Riding the thermals

Pilots can keep gliders in the air for longer by making use of rising warm air



WEIRD WORLD WONDERS

The bizarre but beautiful formations that show Earth's geology rocks

Creating a causeway

How volcanic activity formed 40,000 giant rock pillars

According to legend, the stepping stones of the Giant's Causeway were created by the giant Finn McCool, so that he could walk across the Irish Sea from Northern Ireland to Scotland and fight his rival, Benandonner. In reality, they were formed by volcanic activity around 60 million years ago. Back then, the continents of Europe and North America were attached, but soon began to slowly tear away from each other. As this happened, huge cracks in the Earth's crust formed, causing lava to spew up from below. This lava cooled to form layers of basalt rock on the north coast of Northern Ireland. Over time, the rain eroded away the rock to form a valley, into which more lava flowed. At the top, this lava cooled rapidly, forming a crust that helped to insulate the liquid lava below. As a result, the bottom layer cooled more slowly, causing it to shrink and crack into hexagonal columns. During the most recent ice age, which ended about 11,500 years ago, glaciers eroded the top layer of the rock, exposing the columns beneath. Rising sea levels caused by warmer weather then began to wear them away, creating the varying heights of the columns you can see today.

Lower basalt
Formed by the first volcanic eruptions, these layers are visible as five dark bands of rock in the cliffs.

Multi-sided
Most of the columns are hexagonal, but some have four, five, seven or eight sides.

Giant's Causeway

This geometric landscape formed over millions of years of geological activity

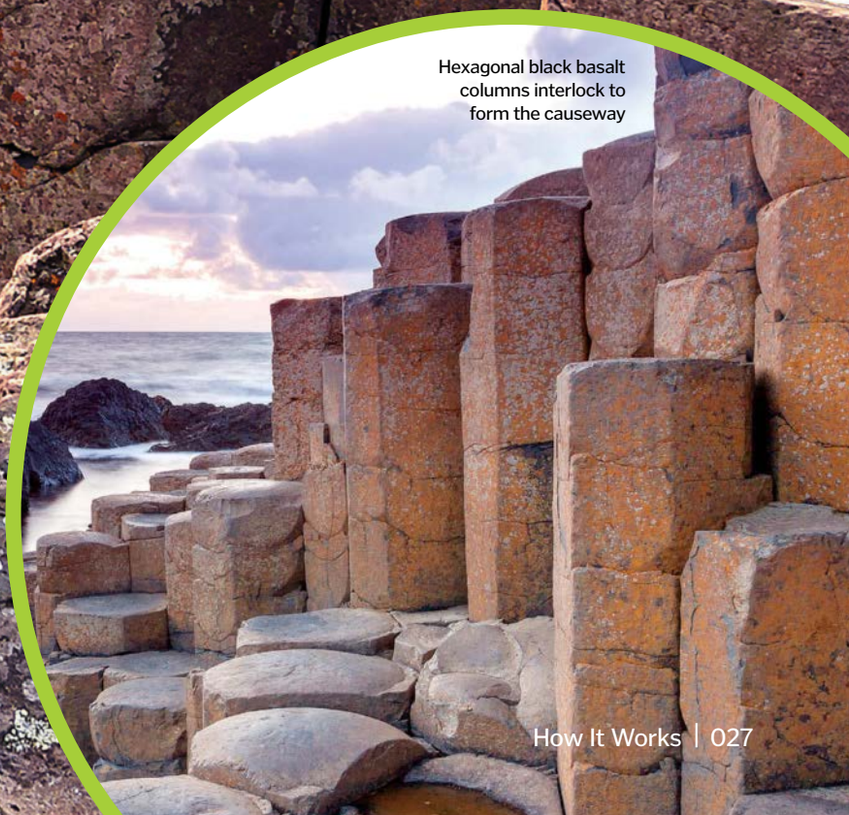
Upper basalt
Further volcanic activity formed a third layer of basalt. This has since worn away on the causeway but can be seen inland.

Middle basalt
A second phase of volcanic activity poured lava onto the surface, which cooled to form the causeway's columns.

"According to legend, the causeway was created by the giant Finn McCool"

A watchful eye
Some columns have been eroded to become completely circular, earning them the nickname 'giant's eyes'.

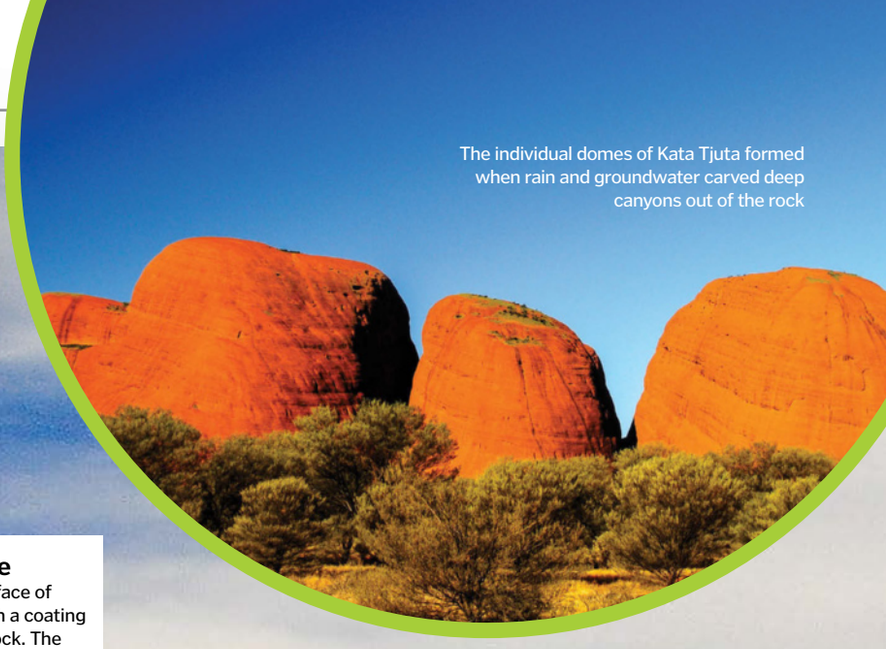
Big and small
The columns vary in size depending on their cooling rates. The slower the lava cooled, the larger the columns created.



Hexagonal black basalt columns interlock to form the causeway

OZ ODDITIES

The Australian outback is home to many strange landmarks



The individual domes of Kata Tjuta formed when rain and groundwater carved deep canyons out of the rock

Flaky surface

Close up, the surface of Uluru is grey, with a coating of red flakes of rock. The flakes' colour is due to the iron in the rock rusting.

Uluru and Kata Tjuta

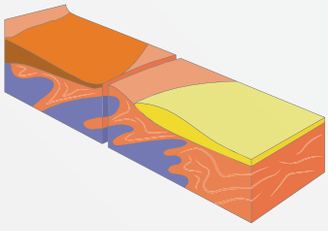
Standing proud against the flat horizon of the Australian outback are two enormous sandstone and rock formations named Uluru and Kata Tjuta. They may look a little out of place but they have been there for millions of years, forming as a result of geological processes.

Uluru towers 863m above sea level, but the majority of the structure lies underground

"They have been there for millions of years, forming as a result of geological processes"

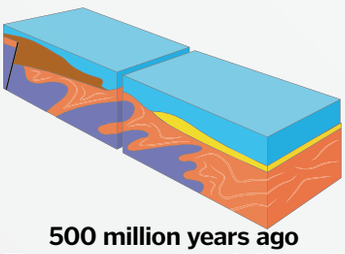
Rocky history

How did the magnificent Uluru and Kata Tjuta rocks form?



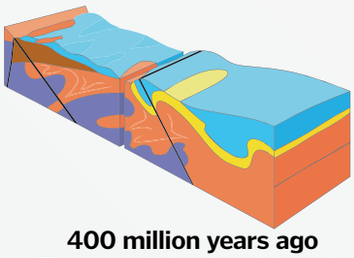
550 million years ago

Rainwater eroded the mountains in the Petermann Ranges, depositing sediment in two fan shapes, one of sand and one of rock, onto the surrounding plain.



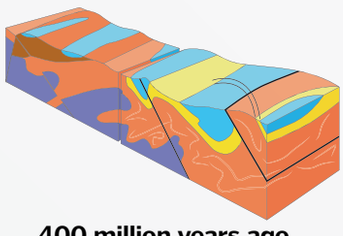
500 million years ago

The area was covered in a shallow sea. A seabed of sand and mud compressed the fans, turning the rock into conglomerate rock, and the sand into arkose sandstone.



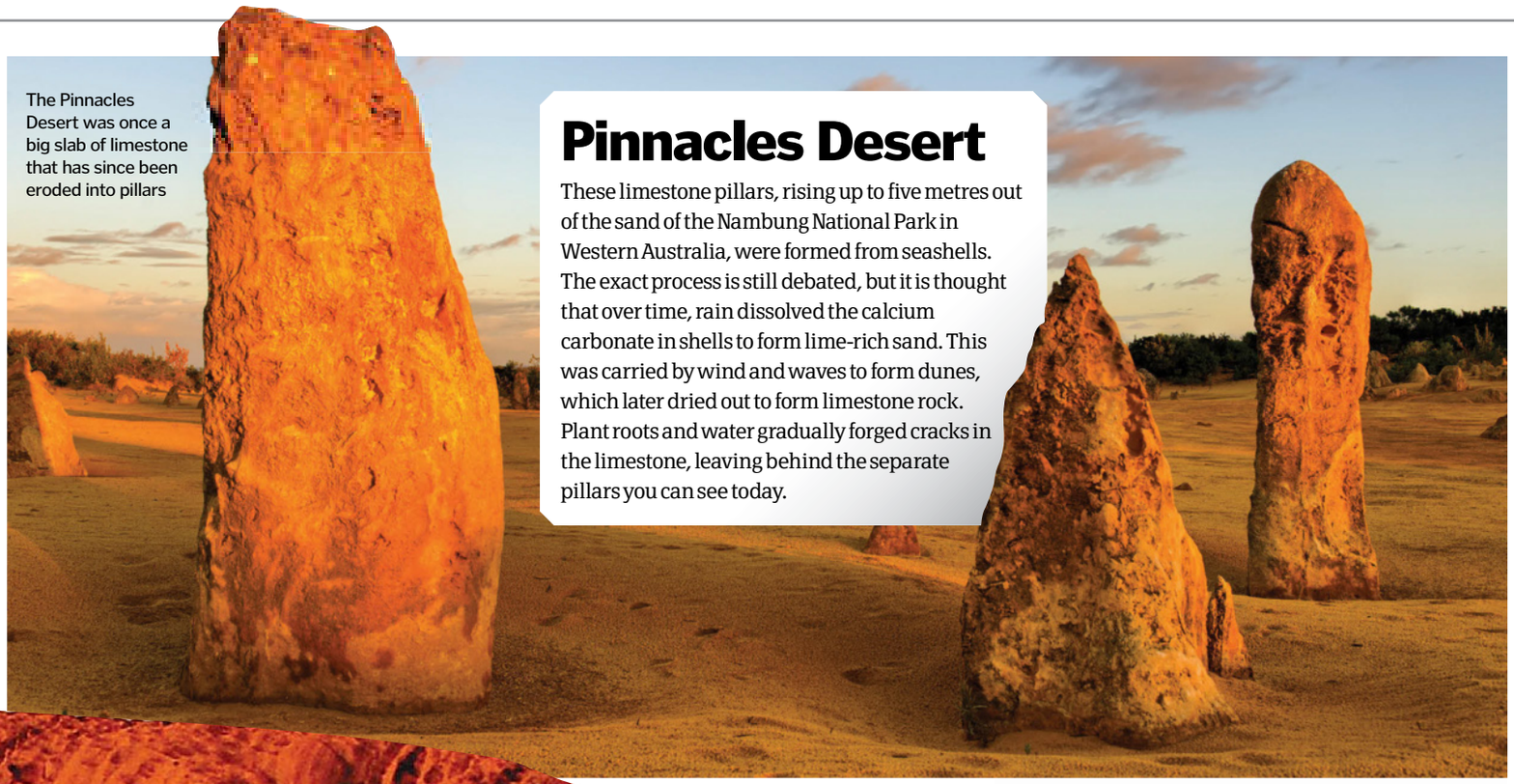
400 million years ago

The sea receded again, and the rocks started to fold and tilt under the immense force of the Earth's shifting tectonic plates.



400 million years ago (continued)

The rocky fan tilted by about 20 degrees, becoming Kata Tjuta. The sandstone fan tilted almost 90 degrees, becoming Uluru.



The Pinnacles Desert was once a big slab of limestone that has since been eroded into pillars

Pinnacles Desert

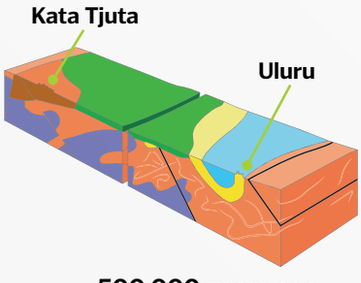
These limestone pillars, rising up to five metres out of the sand of the Nambung National Park in Western Australia, were formed from seashells. The exact process is still debated, but it is thought that over time, rain dissolved the calcium carbonate in shells to form lime-rich sand. This was carried by wind and waves to form dunes, which later dried out to form limestone rock. Plant roots and water gradually forged cracks in the limestone, leaving behind the separate pillars you can see today.

Carved ridges
Some layers of Uluru's rock wear away faster than others, leaving parts of the surface covered in parallel ridges.

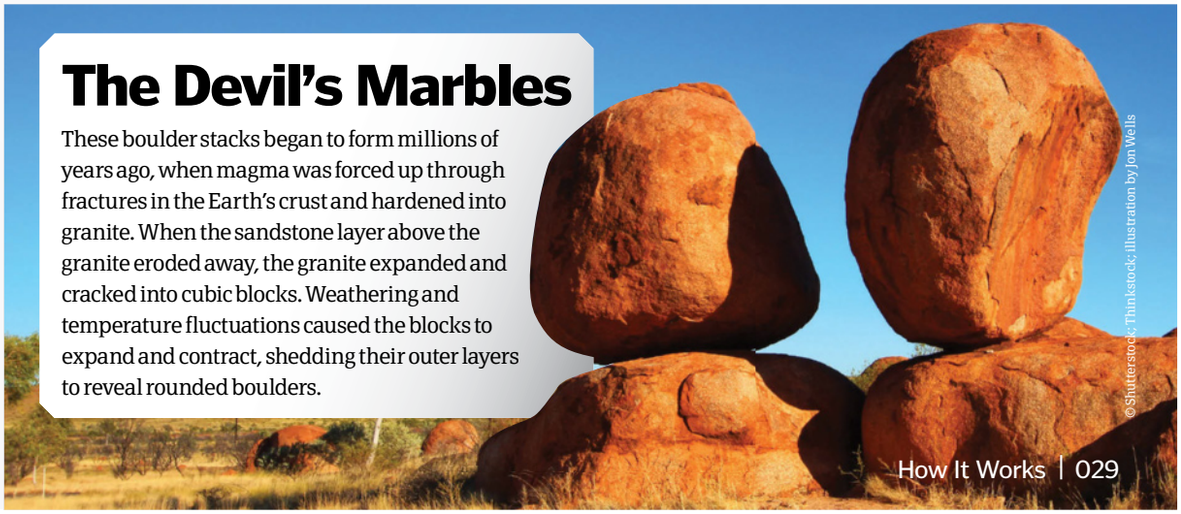
Minerals dissolved in the water from a nearby spring have stained the smooth slope of the wave with streaks of colour

Wave Rock

This granite rock was buried by soil, exposing the top. As granite does not erode easily, the top remained intact, but as rain moistened the soil below, it became acidic and dissolved the base of the rock. The soil has since eroded away, exposing the 15–metre-tall overhanging wave.



500,000 years ago
As the climate became drier, wind-blown sand partly filled the valley between the two slabs of rock that were now protruding from the surface.



The Devil's Marbles

These boulder stacks began to form millions of years ago, when magma was forced up through fractures in the Earth's crust and hardened into granite. When the sandstone layer above the granite eroded away, the granite expanded and cracked into cubic blocks. Weathering and temperature fluctuations caused the blocks to expand and contract, shedding their outer layers to reveal rounded boulders.

HOODOOS

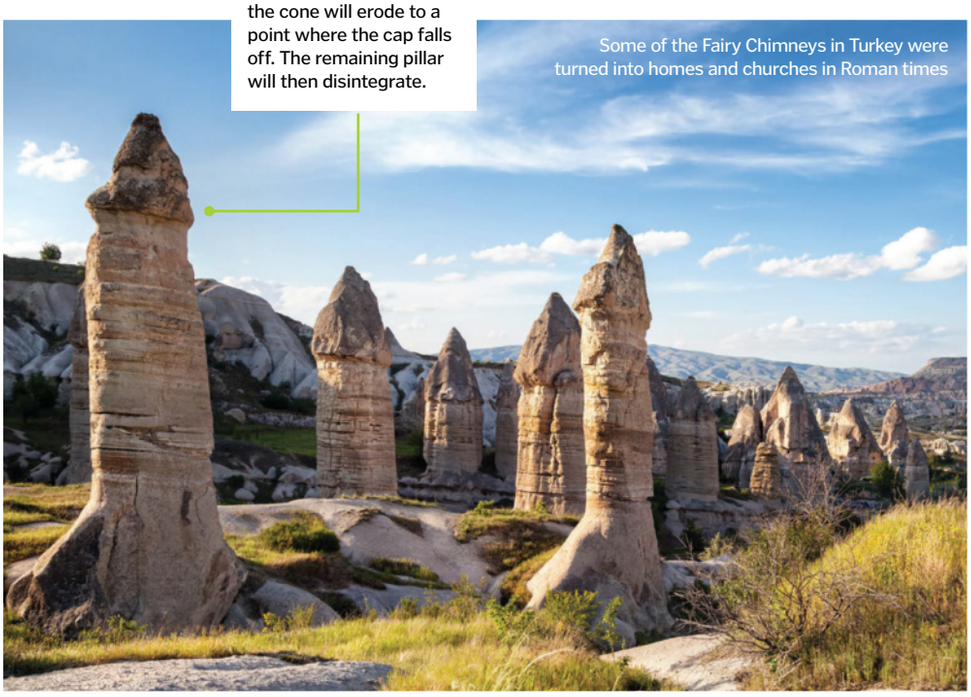
How have these enormous and ancient stacks of rock managed to stay standing?

Typically found rising up from the bottom of arid drainage basins or badlands, hoodoos are tall spires that have been carved out of rock over millions of years. They range in height from 1.5 to 45 metres, and are often striped with the different colours of the rock types that make up their layers. It's these layers that help to prevent these seemingly impossibly balanced stacks from collapsing, as hard rock on top protects the softer lower layers from erosion. Although most hoodoos began life as canyon walls, others have formed in a slightly different way. The famous Fairy Chimneys in Turkey's Cappadocia region are the result of volcanic eruptions that rained down ash, which hardened into a soft porous rock. This rock was covered with a layer of basalt, which eroded into mushroom-shaped caps, protecting it from the elements.

Hoodoos are more abundant in Utah's Bryce Canyon National Park than anywhere else in the world

Erosion rates
The hoodoos are made up of different rock types, which erode at varying speeds. The thinnest parts are mudstone, which erodes easily.

Disintegration
Eventually, the neck of the cone will erode to a point where the cap falls off. The remaining pillar will then disintegrate.



Some of the Fairy Chimneys in Turkey were turned into homes and churches in Roman times

How do hoodoos form?

From flooded canyon to rocky pillars, discover how erosion shaped these rock towers

Empty canyon
A vast lake drains away, leaving behind a canyon with a layer of sediment at the bottom.

Receding walls
Water seeps out of the lower rocks, taking rock material with it and eroding away the walls.

Vertical cracks
Acidic rainwater widens cracks, and expands and contracts as it freezes and thaws, eroding the rock further.

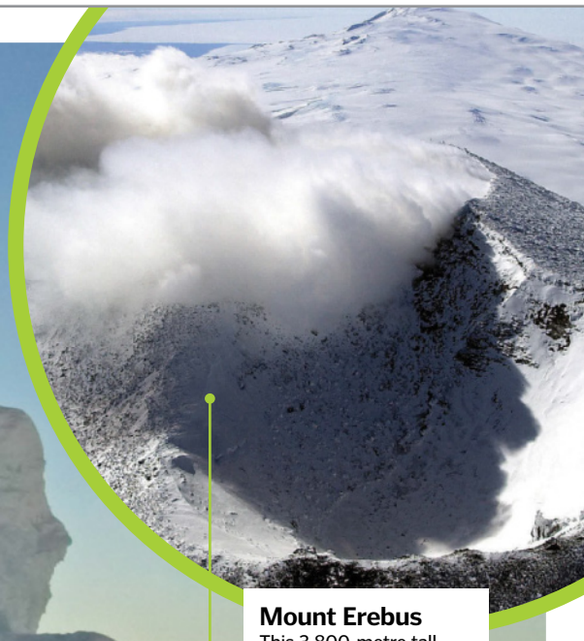
Protective cap
The harder layer of rock on top protects the softer layer beneath it from erosion, forming tall hoodoos.

ICE TOWERS

The amazing ice sculptures built by heat below the surface

It may look like a crooked chimney spewing smoke into the cold Antarctic air, but there's no fire to be found inside this strange structure. Instead, you'll find a cave, carved out of the ice by the heat from the nearby Mount Erebus volcano. The steam rising from these caves instantly freezes as it hits the sub-zero air above, forming a hollow tower of ice above. The scientific name for these features is ice fumaroles – a fumarole being any volcanic vent that ejects gas or steam. They can be found all over the world, and even on Mars, but only a few places are cold enough to turn their emissions to ice.

"Steam from the caves instantly freezes as it hits the sub-zero air above"



Mount Erebus
This 3,800-metre tall volcano in Antarctica is surrounded by hundreds of ice fumaroles.

Ice fumaroles grow as more steam rises and freezes; some reach heights of 18 metres

Search for life
The ice caves beneath the towers are of interest to scientists, as they may be home to many as yet undiscovered species.

A land of ice and fire

Despite being located in the centre of a stationary tectonic plate, Antarctica still manages to be a hotbed of volcanic activity. This is all down to the West Antarctic Rift, an area where the tectonic plates are slowly moving apart. Along this rift, the Earth's crust has thinned, allowing magma to rise to the surface and create enormous volcanoes. While many of the volcanoes are now extinct, others are still ejecting hot gas and lava, with the most active being Mount Erebus on Ross Island. Mount Erebus is one of only a few volcanoes to have an open lava lake. While the central crater on most volcanoes is covered with a solid slab of cooled molten rock, the one on this volcano is uncovered, exposing the hot magma inside. Several low-level eruptions occur every day, ejecting scorching lava bombs onto the surrounding landscape as a result.

Mount Erebus is the second tallest volcano in Antarctica, and the most southerly active volcano on Earth

DEVILS TOWER

The magnificent American monument with mysterious origins

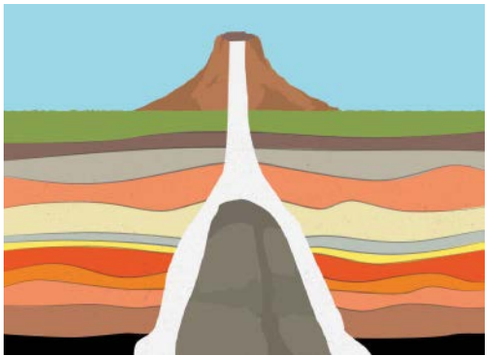
Among the pine forests of Crook County, Wyoming, stands an enormous lump of rock reaching high up into the sky. Known as Devils Tower, it is so awe-inspiring that in 1906, President Theodore Roosevelt established it as the United States' first national monument, but no one quite knows how it formed. What we do know is that it is made from phonolite porphyry, an igneous rock that is formed when magma cools and crystallises. In this case, as the magma cooled, it also contracted, cracking the rock into the polygonal columns that now make up the Tower. Most geologists agree that the rock formed when magma rose up into the surrounding sedimentary rock, but there are three possible theories for how this happened.

Columns
The Tower's almost vertical columns were formed as magma cooled and condensed into igneous rock.

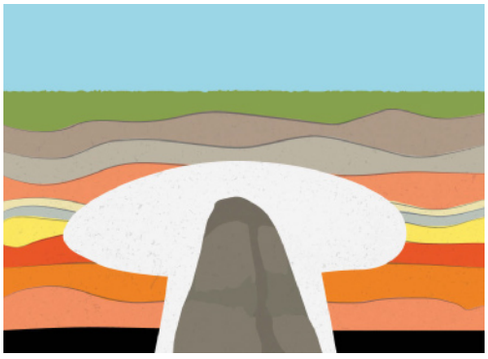
Erosion continues
The Tower is still eroding today, and the land surrounding it is littered with rocks and rubble that have fallen from the stucture.

Formation theories

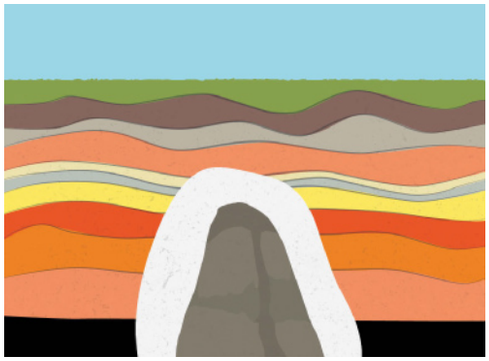
Three popular ideas of how Devils Tower came to be



Theory 1 – Volcanic plug
The rock is the neck of an extinct volcano or a plug that lay beneath it. Although there is no evidence of volcanic activity, such as ash or lava flows, in the area, this material could have simply eroded away.



Theory 2 – Laccolith
The Devils Tower is a laccolith, a large, mushroom-shaped mass of igneous rock, which spreads between the layers of sedimentary rocks beneath the Earth's surface. The rounded bulge on top has eroded away.



Theory 3 – Stock
Magma beneath the Earth's surface cooled and crystallised to form the lump of rock you can see today. Over time it was exposed by erosion wearing away the rock above it.

THE WAVE

Arizona's sweeping rock of many colours was once a dinosaur stomping ground

This spectacular wave structure started to form 190 million years ago when dinosaurs walked the Earth, and their footprints can still be seen in the rock today. The Wave began as sand dunes, which were compacted and solidified to become sandstone. The smooth undulating shape is the result of very slow erosion, originally caused by the flow of water, which deposited various minerals into the rock to create the colourful stripes that swirl through it. When the water dried up, wind erosion took over, and continues to carve the rock to this day.

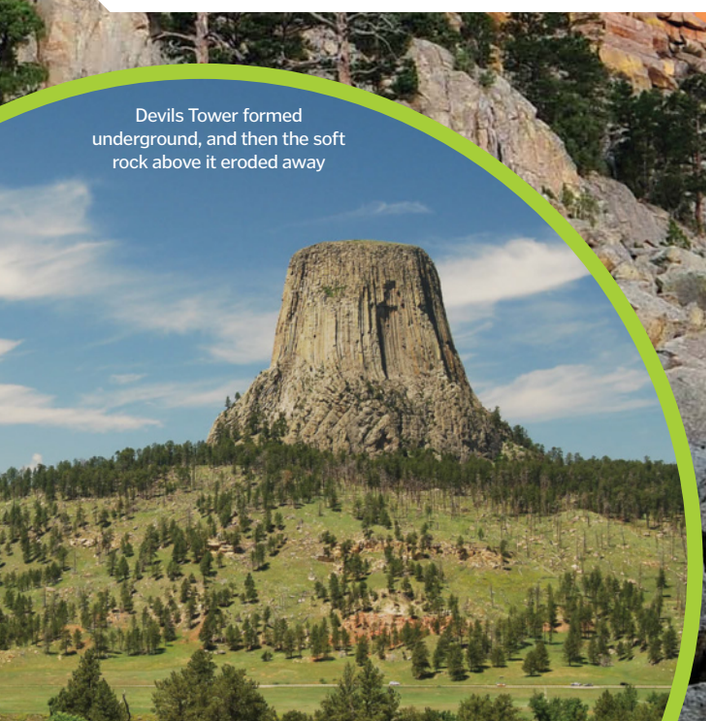
To help protect the soft rock of the Wave, only 20 visitors are permitted each day

SAND TUFA

The bizarre cauliflower formations that sprout when conditions are just right

They may look like the flowering head of a popular vegetable, but these alien-like structures are actually known as tufa. They form underwater in alkaline lakes, such as California's Mono Lake, at the site of freshwater springs rich in calcium. When the calcium comes into contact with carbonates in the surrounding water, calcium carbonate forms, also known as limestone. The limestone settles on the lake bed, and as more and more is deposited, a tower begins to grow. Most of these structures remain obscured by water, but in lakes where the water levels have dropped, they become visible for all to see.

Mono Lake in California has one of the most impressive tufa displays



Devils Tower formed underground, and then the soft rock above it eroded away

CAVE OF CRYSTALS

The spectacular secret treasures that have been growing beneath Mexico for 500,000 years

When miners broke through the wall of a Mexican silver mine, 300 metres underground in the year 2000, they could never have expected the site that greeted them. Enormous, translucent beams of crystal towered above them, criss-crossing from either side of a sweltering cave. Normally flooded with water, the mining company's pumping operations had made the cave accessible to humans for the first time, uncovering the largest natural-grown crystals ever found.

The reason why the crystals had been able to grow so large is because of the precise conditions inside the cave. Lying above a magma chamber on an ancient fault line, the water inside the cave, which was rich in the mineral anhydrite, had been kept at a steady temperature of 58 degrees Celsius. At this temperature, anhydrite slowly dissolves into gypsum, a soft mineral that grows into crystals. These conditions have prevailed for the past 500,000 years, allowing the gypsum crystals to grow to their impressive heights, but have also made the cave inhospitable. The high temperature and humidity means that humans can only survive inside for short periods of time, even when wearing suits lined with ice and carrying a breathing system that feeds cold air into the lungs.

With studies of the crystals still ongoing, there is currently some debate about what to do when the Naica mine closes. Geologists must decide whether to continue pumping out the water to allow access to the cave, or let it flood again so that the crystals can continue to grow.

Ancient bacteria
Researchers took samples of some of the crystals in order to identify any bacteria that lived in these extreme conditions.

Crystal breeding
A magma chamber beneath the cave heated the mineral-rich water to a stable 50˚C, providing ideal conditions for crystal growth.

The Cave of Crystals is buried beneath the Naica mountain in the Chihuahuan Desert of Mexico

"Humans can only survive inside the cave for short periods of time"

Geologists discovered how the crystals formed by studying tiny pockets of fluid trapped inside them

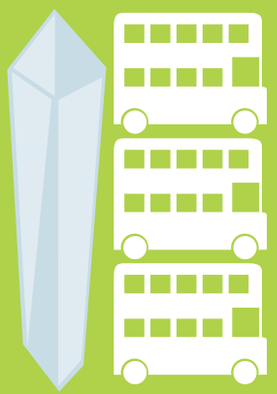
Cooling suit
In order to explore the cave, scientists wore special suits lined with refrigerating tubes, as well as breathing apparatus.

Without specialist breathing equipment, moisture in the cave's humid air would condense on the lungs

Cave by numbers

Unbelievable stats about the deadly cave of wonders

11m
THE LENGTH OF THE TALLEST CRYSTAL, ALMOST THE HEIGHT OF THREE DOUBLE-DECKER BUSES



55 tons
THE WEIGHT OF THE LARGEST CRYSTAL, EQUIVALENT TO NINE AFRICAN ELEPHANTS

10min
The length of time you can survive in the cave without any equipment

2hrs
The length of time you can survive in the cave with proper equipment

9x27m
The size of the Cave of Crystals – slightly larger than a tennis court

90-100%
HUMIDITY INSIDE THE CAVE

20 KG
Weight of the cooling suit that must be worn inside the cave

50 °C
THE TEMPERATURE INSIDE THE CAVE

Animal lifespans

With a new record set, find out how long different species survive on our planet

1 YEARS

Insect
Most insects live for a year or less. The mayfly has the shortest animal lifespan, living for just one day!

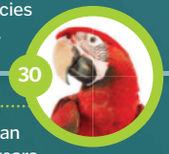
Grey wolf 8

Toad 10
The common toad lives for up to 40 years, but most species live for just five to ten.

12 **Sheep**

15 **Cat**
Domestic cats typically live for 15 years, or 76 in 'cat years'.

Toucan 20

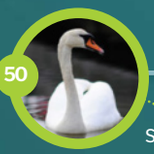


30 **Parrot**
Most parrot species have an average lifespan of over 30 years. Cockatoos and Amazonian parrots can live for up to 75 years.

35 **Rhinoceros**

25 **Horse**
The average lifespan of a horse is 20 to 25 years, although this varies depending on the breed.

40 **Hippopotamus**



50 **Swan**
Swans can live for up to 50 years, but the dangers of the wild mean that many only reach seven to 12 years old.

Human
The global average life expectancy for humans is 71 years.

70

60 **Elephant**
African elephants live for 60 to 70 years in the wild, although their lifespan typically halves in captivity.

80 **Green sea turtle**

90 **Blue whale**
The world's largest animals have an average lifespan of 80 to 90 years, while other species of whale can live to be 200.

BORN WHEN... Queen Elizabeth II was born in 1926

Pearl mussel
One of the longest living invertebrates, these molluscs can live for over a century, growing an extra layer on their shell each year.

100

BORN WHEN... World War I was underway

120 140 160 180 200 220 240 260 280 300 320 340 360 380

150 **Giant tortoise**
The slow metabolism of giant tortoises means they have an average lifespan of over 100 years, with some living to the ripe old age of 150.

BORN WHEN...
Abraham Lincoln was president in the 1860s

400 **Greenland shark**
It was recently discovered that Greenland sharks can live for 400 years or more, due to their incredibly slow growth rate of one centimetre per year.

BORN WHEN...
Shakespeare died in 1616

The oldest vertebrate on Earth

Scientists have discovered that Greenland sharks are the longest-lived vertebrates on Earth. They have a growth rate of one centimetre per year, with an average lifespan of 390 years. Scientists used radiocarbon dating to work out the date of the proteins at the centre of the lenses in the eyes of 28 female sharks. These would have formed before the shark was born, revealing that the group ranged from 272 to 512 years old.

Tree kangaroos

Meet the canopy-dwelling cousins of kangaroos and wallabies

Native to the rainforests of Australia, Indonesia and Papua New Guinea, tree kangaroos diverged from their ground-dwelling cousins on the evolutionary tree about five million years ago, and have since adapted to life in the canopy.

Unlike normal kangaroos, they're much smaller, and have arms and legs of a similar length, making them well-adapted for climbing. However, they're still able to hop between trees and down to the ground when they need to evade danger. As solitary animals, tree kangaroos usually only form social bonds for mating and when a female cares for her young. Joeys typically stay in their mother's pouch for ten months, and will remain close by for another eight. As they have no threats from other tree-climbing mammals, they usually thrive in their treetop home, feasting on leaves, fruit, flowers and bark. However, human-caused threats, such as hunting and habitat loss, have landed them on the endangered species list.

In the canopy

What makes these curious creatures so good at climbing trees?

Strong forearms
Muscular front limbs make climbing tall trees easier.

Long tail
A long, thick tail helps the tree kangaroos to balance on tree branches.

Shock-absorbent joints
Their limb joints can withstand great leaps from tree to tree.

Wide feet
Claws and foot pads help them to grip onto tree trunks and branches.

Heathland

Landscapes that rare plants and wildlife call home

The largest area of heathland in Europe is in the New Forest, which occupies over 10,000 hectares

The heathlands of the UK and Europe are a haven for flora and fauna. The unique landscape plays host to dwarf shrubs, heathers and gorses that exist on the acidic, low-nutrient soil. It also acts as a habitat for the UK's native reptile species, such as adders and sand lizards, and birds like Dartford warblers and woodlarks, as well as thousands of invertebrates. Only found in temperate climates, heathlands are divided into upland and lowland categories, which occur above and below altitudes of 300 metres above sea level.

Radio-carbon dating has shown that the first heathlands date back some 14,000 years. However, most of the heathlands that we see today are down to the arrival of Bronze Age settlers around 4,000 years ago, who cleared trees to grow crops and graze livestock. The UK is home to 95,000 hectares of lowland heathland, 20 per cent of Europe's total amount. 15 per cent of this is being lost every decade, so a number of organisations are providing active management solutions to help these environments to survive.

Meet the manta ray

These leviathans may be large enough to cover your car, but they're really just gentle ocean giants

Mantas often travel with suckerfish – a tag-along species that takes advantage of speed and status

Cruising both the open oceans and the sunlit tropical shallows, a manta ray cuts a pretty imposing silhouette in the water. With undulating pectoral fins that look like gargantuan wings, these creatures can span in excess of seven metres. There are two distinct supersized species: Manta birostris, the giant oceanic manta ray, and Manta alfredi, the reef manta ray.

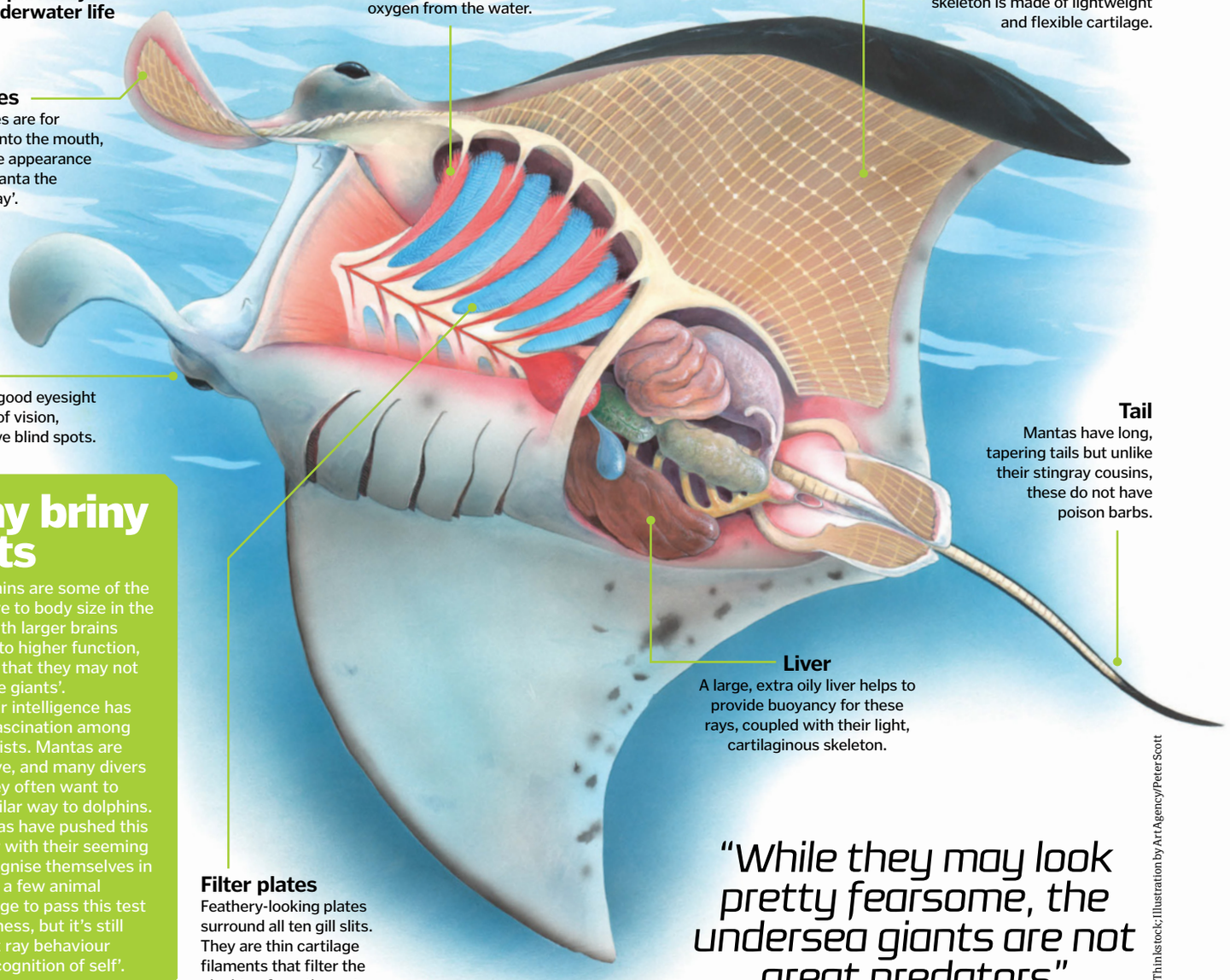
The giant oceanic manta ray is migratory, and uses the ocean currents as highways to traverse huge distances in search of the best feeding grounds. The smaller resident reef manta prefers to stay closer to shallow waters, swimming near coastal reefs in the tropics and subtropics.

Manta rays are solitary creatures, and only really come together to breed. These interactions can often begin at feeding areas, or at 'cleaning stations' – areas of coral reef where fish and shrimp feed on parasites on the manta's skin.

While they may look pretty fearsome, the undersea giants are not great predators, instead choosing to feed on plankton – tiny microscopic creatures suspended in the water. The rays will open their mouths wide, and let the water flow over their gills as they filter out tasty morsels. Mantas will eat around 13 per cent of their body weight each week. When the plankton is just right, feeding can get acrobatic, with the massive rays making loop-the-loops and corkscrew spirals in the water to ensure they get their fill.

Manta anatomy

Streamlined and strong, these rays are perfectly adapted to underwater life



Gills
The gills are full of blood vessels that absorb oxygen from the water.

Cartilage
Unlike the dense bone of many other fish, the manta ray's skeleton is made of lightweight and flexible cartilage.

Cephalic lobes
These appendages are for funnelling water into the mouth, and their horn-like appearance has earned the manta the nickname 'devil ray'.

Eyes
Manta rays have good eyesight with a wide field of vision, although they have blind spots.

Tail
Mantas have long, tapering tails but unlike their stingray cousins, these do not have poison barbs.

Liver
A large, extra oily liver helps to provide buoyancy for these rays, coupled with their light, cartilaginous skeleton.

Filter plates
Feathery-looking plates surround all ten gill slits. They are thin cartilage filaments that filter the plankton from the water.

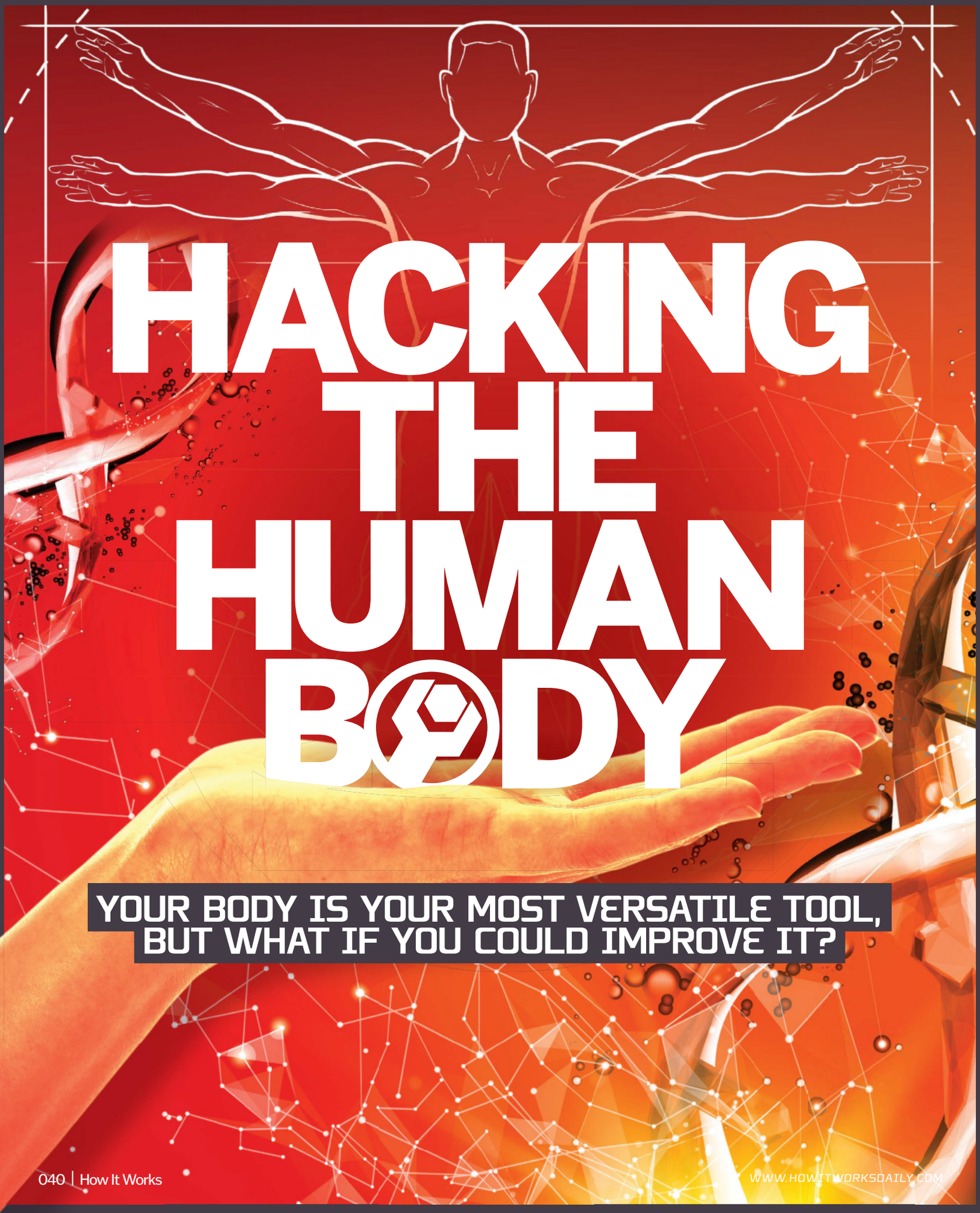
Brainy briny beasts

Manta ray brains are some of the largest relative to body size in the ocean, and with larger brains often related to higher function, this indicates that they may not be just 'simple giants'.

In fact, their intelligence has long been a fascination among marine scientists. Mantas are very inquisitive, and many divers claim that they often want to 'play' in a similar way to dolphins.

Now, mantas have pushed this a step further with their seeming ability to recognise themselves in a mirror. Only a few animal species manage to pass this test of self-awareness, but it's still debated what ray behaviour counts as 'recognition of self'.

"While they may look pretty fearsome, the undersea giants are not great predators"



HACKING THE HUMAN BODY

YOUR BODY IS YOUR MOST VERSATILE TOOL, BUT WHAT IF YOU COULD IMPROVE IT?

We are limited by our biology: prone to illness, doomed to wear out over time, and restricted to the senses and abilities that nature has crafted for us over millions of years of evolution. But not any more.

Biological techniques are getting cheaper and more powerful, electronics are getting smaller, and our understanding of the human body is growing. Pacemakers already keep our hearts beating, hormonal implants control our fertility, and smart glasses augment our vision. We are teetering on the edge of the era of humanity 2.0, and some enterprising individuals have already made the leap to the other side.

While much of the technology developed so far has had a medical application, people are now choosing to augment their healthy bodies to extend and enhance their natural abilities.

Kevin Warwick, a professor of cybernetics at Coventry University, claims to be the "world's first cyborg". In 1998, he had a silicon chip implanted into his arm, which allowed him to open doors, turn on lights and activate computers without even touching them. In 2002, the system was upgraded to communicate with his nervous system; 100 electrodes were linked up to his median nerve.

Through this new implant, he could control a wheelchair, move a bionic arm and, with the help of a matched implant fitted into his wife, he was even able to receive nerve impulses from another human being.

Professor Warwick's augmentations were the product of a biomedical research project, but waiting for these kinds of modifications to hit the mainstream is proving too much for some enterprising individuals, and hobbyists are starting to experiment for themselves.

Amal Graafstra is based in the US, and is a double implantee. He has a Radio Frequency Identification (RFID) chip embedded in each hand: the left opens his front door and starts his motorbike, and the right stores data uploaded from his mobile phone. Others have had magnets fitted inside their fingers, allowing them to sense magnetic fields, and some are experimenting with aesthetic implants, putting silicon shapes and lights beneath their skin. Meanwhile, researchers are busy developing the next generation of high-tech equipment to upgrade the body still further.

This article comes with a health warning: we don't want you to try this at home. But it's an exciting glimpse into some of the emerging technology that could be used to augment our bodies in the future. Let's dive in to the sometimes shady world of biohacking.

> *"We are teetering on the edge of the era of humanity 2.0"*

IMPLANTS

Professional and amateur biohackers are exploring different ways of augmenting our skin

Electronic tattoos

Not so much an implant as a stick-on mod, this high-tech tattoo from the Massachusetts Institute of Technology (MIT) can store information, change colour, and even control your phone.

Created by the MIT Media Lab and Microsoft Research, DuoSkin is a step forward from the micro-devices that fit in clothes, watches and other wearables. These tattoos use gold leaf to conduct electricity against the skin, performing three main functions: input, output and communication. Some of the tattoos work like buttons or touch pads. Others change colour using resistors and temperature-sensitive chemicals, and some contain coils that can be used for wireless communication.

The electronic tattoos work as touch sensors, change colour, and receive Wi-Fi signals

Fingertip magnets

Tiny neodymium magnets can be coated in silicon and implanted into the fingertips. They respond to magnetic fields produced by electrical wires, whirring fans and other tech. This gives the wearer a 'sixth sense', allowing them to pick up on the shape and strength of invisible fields in the air.

The implants allow the wearer to pick up small magnetic objects

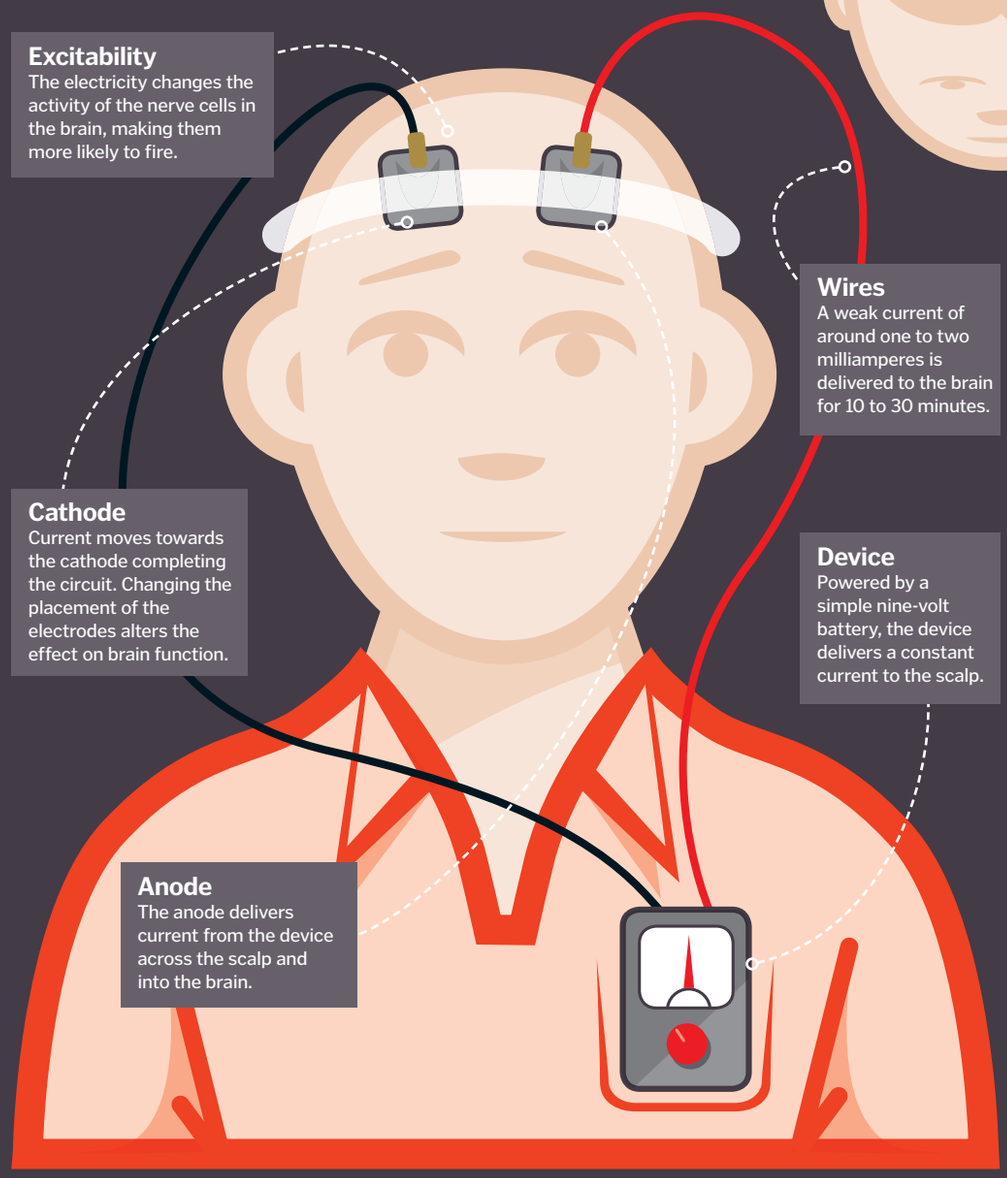
Under-skin lights

Some implants are inserted under the skin to augment the appearance of the body. The procedure involves cutting and stitching, and is often performed by tattoo artists or body piercers. The latest version, created by a group in Pittsburgh, even contains LED lights. This isn't for the faint of heart – anaesthetics require a license, so fitting these is usually done without.

Grindhouse Wetware makes implantable lights that glow from under the skin

Buzzing the brain

Transcranial DC stimulation sends electrical signals through the skull to enhance performance



Motor control
If the current is applied over the motor cortex, it increases excitability of the nerve cells responsible for movement.

Visual perception
Visual information is processed at the back of the brain, and electrodes placed here can augment our ability to interpret our surroundings.

Working memory
Stimulation of the front of the brain seems to improve short-term memory and learning.

Excitability
The electricity changes the activity of the nerve cells in the brain, making them more likely to fire.

Wires
A weak current of around one to two milliamperes is delivered to the brain for 10 to 30 minutes.

Cathode
Current moves towards the cathode completing the circuit. Changing the placement of the electrodes alters the effect on brain function.

Device
Powered by a simple nine-volt battery, the device delivers a constant current to the scalp.

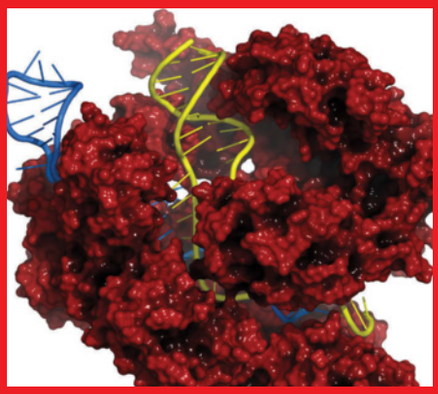
Anode
The anode delivers current from the device across the scalp and into the brain.

Gene editing

In 2013, researchers working in gene editing made a breakthrough. They used a new technique to cut the human genome at sites of their choosing, opening the floodgates for customising and modifying our genetics.

The system that they used is called CRISPR. It is adapted from a system found naturally in bacteria, and is composed of two parts: a Cas9 enzyme that acts like a pair of molecular scissors, and a guide molecule that takes the scissors to a specific section of DNA.

What scientists have done more recently is to hijack this system. By 'breaking' the enzyme scissors, the CRISPR system no longer cuts the DNA. Instead, it can be used to switch the genes on and off at will, without changing the DNA sequence. At the moment, the technique is still experimental, but in the future it could be used to repair or alter our genes.



The CRISPR complex works like a pair of DNA-snipping scissors

HACKING THE BRAIN

With the latest technology we can decipher what the brain is thinking, and we can talk back

The human brain is the most complex structure in the known universe, but ultimately it communicates using electrical signals, and the latest tech can tap into these coded messages.

Prosthetic limbs can now be controlled by the mind; some use implants attached to the surface of the brain, while others use caps to detect electrical activity passing across the scalp. Decoding signals requires a lot of training, and it's not perfect, but year after year it is improving.

It is also possible to communicate in the other direction, sending electrical signals into the brain. Retinal implants pick up light, code it into electrical pulses and deliver them to the optic nerve, and cochlear implants do the same with sound in the ears via the cochlear nerve. And, by attaching electrodes to the scalp, whole areas of the brain can be tweaked from outside.

"Prosthetic limbs can now be controlled by the mind"

Transcranial direct current stimulation uses weak currents that pass through skin and bone to the underlying brain cells. Though still in development, early tests indicate that this can have positive effects on mood, memory and other brain functions. The technology is relatively simple, and companies are already offering the kit to people at home. It's even possible to make one yourself.

However, researchers urge caution. They admit that they still aren't exactly sure how it works, and messing with your brain could have dangerous consequences.

Exoskeletons and virtual reality

At the 2014 World Cup in Brazil, Miguel Nicolelis from Duke University teamed up with 29-year-old Juliano Pinto to showcase exciting new technology. Pinto is paralysed from the chest down, but with the help of Nicolelis' mind-controlled exoskeleton and a cap to pick up his brainwaves, he was able to stand and kick the official ball.

The next step in Nicolelis' research has been focused on retraining the brain to move the legs – and this time he's using VR. After months of controlling the walking of a virtual avatar with their minds, eight people with spinal-cord injuries have actually regained some movement and feeling in their own limbs.

Electrodes can pick up neural impulses, so paralysed patients are able to control virtual characters with their brain activity

Exosuits can amplify your natural movement, while some models can even be controlled by your mind

Community biology labs

We spoke to Tom Hodder, technical director at London Biological Laboratories Ltd to learn more about public labs and the biohacking movement

Interview bio:
Tom Hodder studied medicinal chemistry and is a biohacker working on open hardware at London Biohackspace.

What is the London Biohackspace?
The London Biohackspace is a biolab at the London Hackspace on Hackney Road. The lab is run by its members, who pay a small monthly fee. In return they can use the facilities for their own experiments and can take advantage of the shared equipment and resources. In general the experiments are some type of microbiology, molecular or synthetic biology, as well as building and repairing biotech hardware.

Who can get involved? Is the lab open to anyone?
Anyone can join up. Use of the lab is subject to a safety induction. There is a weekly meet-up on Wednesdays at 7.30pm, which is open to the public.

Why do you think there is such an interest in biohacking?
Generally, I think that many important problems, such as food, human health, sustainable resources (e.g. biofuels) can be potentially mitigated by greater understanding of the underlying processes at the molecular biological level. I think that the biohacking community is orientated towards the sharing of these skills and knowledge in an accessible way. Academic research is published, but research papers are not the easiest reading, and the details of commercial research are generally not shared unless it's patented. More recently, much of the technology required to perform these experiments is becoming cheaper and more accessible, so it is becoming practical for biohacking groups to do more interesting experiments.

Where do you see biohacking going in the future?
I think in the short term, the biohacking groups are not yet at an equivalent level to technology and resources to the universities and commercial research institutions. However in the next five years, I expect more open biolabs and biomakerspaces to be set up and the level of sophistication to increase.
I think that biohacking groups will continue to perform the service of communicating the potential of synthetic and molecular biology to the general public, and hopefully do that in an interesting way.

Community labs are popping up all over the world, providing amateur scientists with access to biotech equipment

BUILDING FUTURE YOU

A closer look at some of the emerging tech that will allow you to customise your body

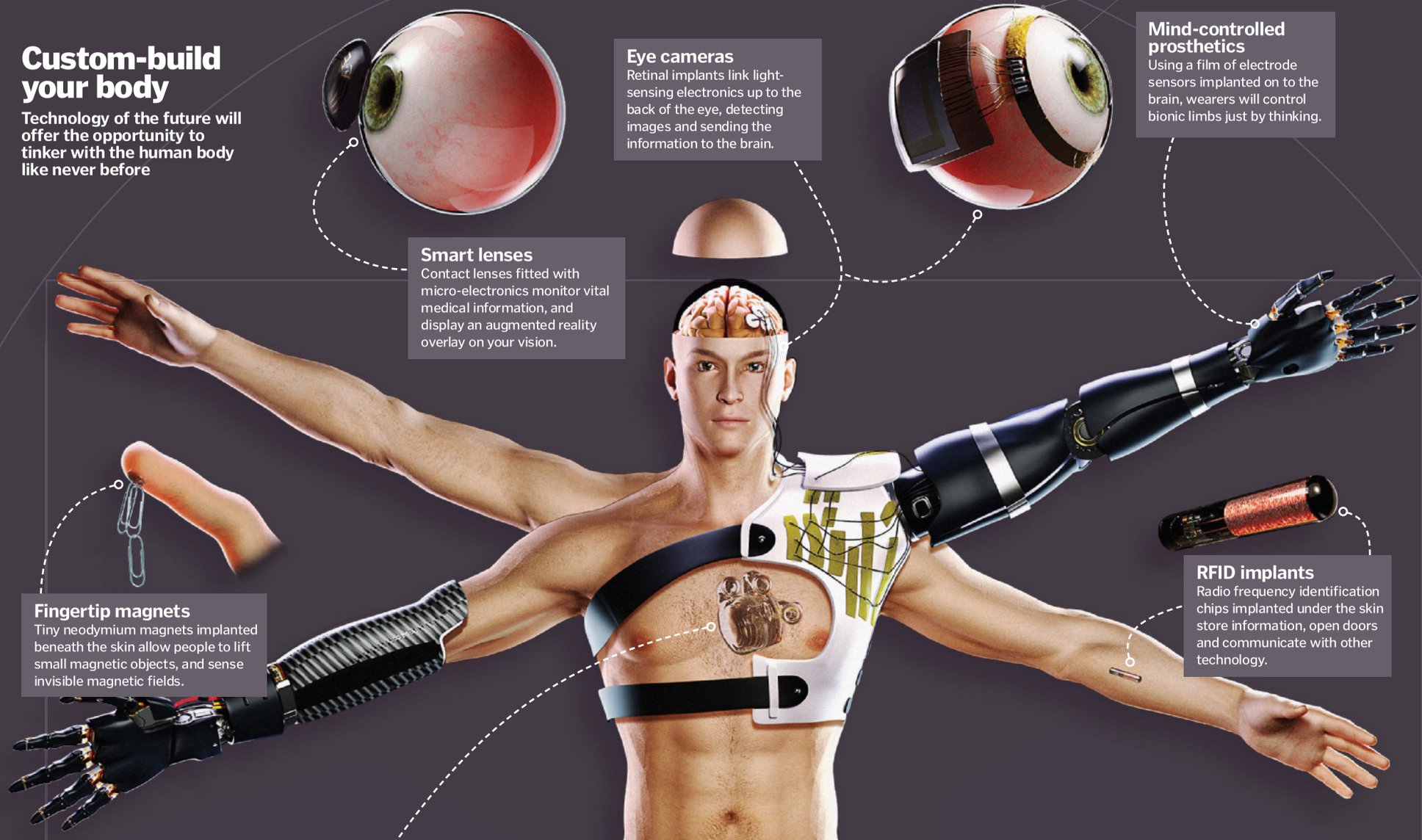
Self-improvement is part of human nature, and technology is bringing unprecedented possibilities into reach. Much of the development up until this point has had a medical purpose in mind, including prosthetic limbs for amputees, exoskeletons for paralysis, organs for transplant, and light sensors for the blind. However, with the advent of wearable technology, and a growing community of amateur and professional biotechnology tinkerers, there is increased interest in augmenting the healthy human body.

The first cyborgs already walk among us, fitted with magnetic senses, implanted with microchips, and talking to technology using their nervous systems. At the moment, many devices are experimental, sometimes even homemade and unlicensed. However, the field is opening up, and the possibilities are endless.

So, what does the future hold for a customisable you? Medical implants could monitor, strengthen, heal or replace our organs. We could add extra senses, or improve the ones we already have. And, one day, we might be able to tap straight into the internet with our minds.

Custom-build your body

Technology of the future will offer the opportunity to tinker with the human body like never before



Eye cameras
Retinal implants link light-sensing electronics up to the back of the eye, detecting images and sending the information to the brain.

Mind-controlled prosthetics
Using a film of electrode sensors implanted on to the brain, wearers will control bionic limbs just by thinking.

Smart lenses
Contact lenses fitted with micro-electronics monitor vital medical information, and display an augmented reality overlay on your vision.

Fingertip magnets
Tiny neodymium magnets implanted beneath the skin allow people to lift small magnetic objects, and sense invisible magnetic fields.

RFID implants
Radio frequency identification chips implanted under the skin store information, open doors and communicate with other technology.

Bionic organs
Replacement organs will be grown from real human cells in the lab, or reconstructed using synthetic materials and electronics.

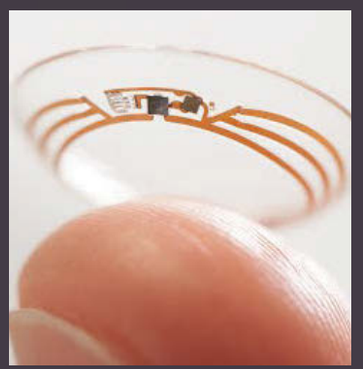
Exoskeleton support
Robotic exoskeletons support the wearer's limbs, using hydraulics in place of muscles, and hinges in place of joints.

Interchangeable limbs
Advanced prosthetics could give amputees superhuman abilities, and the option to switch between designs to suit the situation.

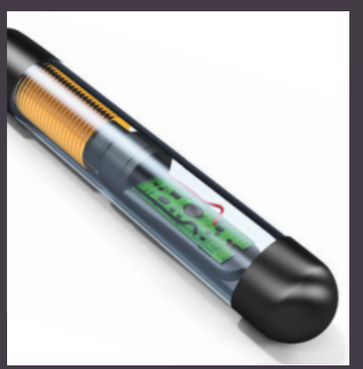
Smart bandages
Wound dressings will be equipped with sensors to monitor healing and flag up the first signs of infection by turning fluorescent green.

Electronic tattoos
Gold-leaf temporary tattoos can be used as touch sensors, colour-changing indicators, and for Wi-Fi communications.

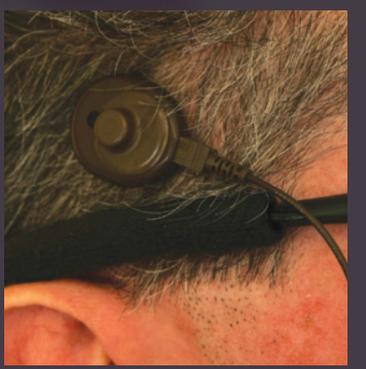
"Many devices are experimental, sometimes even homemade"



Google is developing a contact lens that senses blood sugar by analysing tears



This RFID chip shows the coiled copper antenna it uses to communicate



The Argus implant's camera and transmitter signal to the optic nerve

The i-limb hand can be moved by gestures, apps, muscle signals or proximity sensors

Ekso moves legs in response to upper body movement

DID YOU KNOW? *The oldest prosthetic is a wood and leather toe, found on an Ancient Egyptian mummy from 950–710 BCE*

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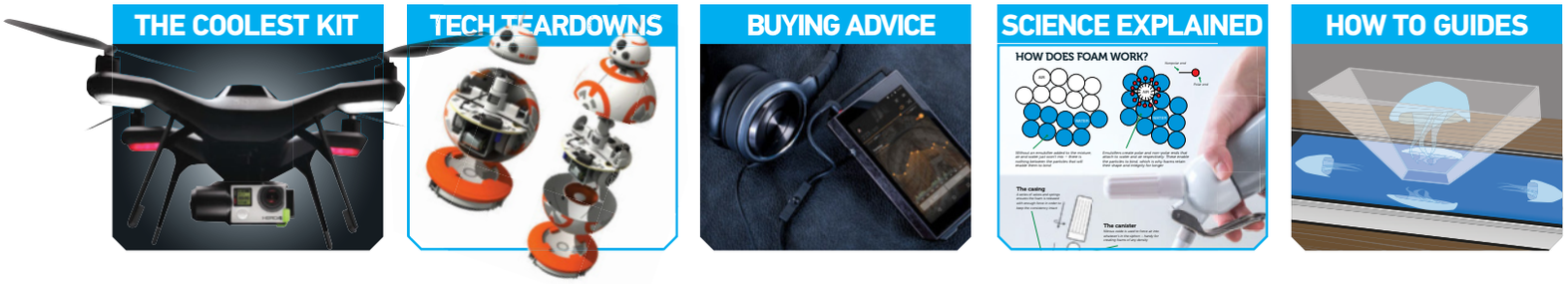

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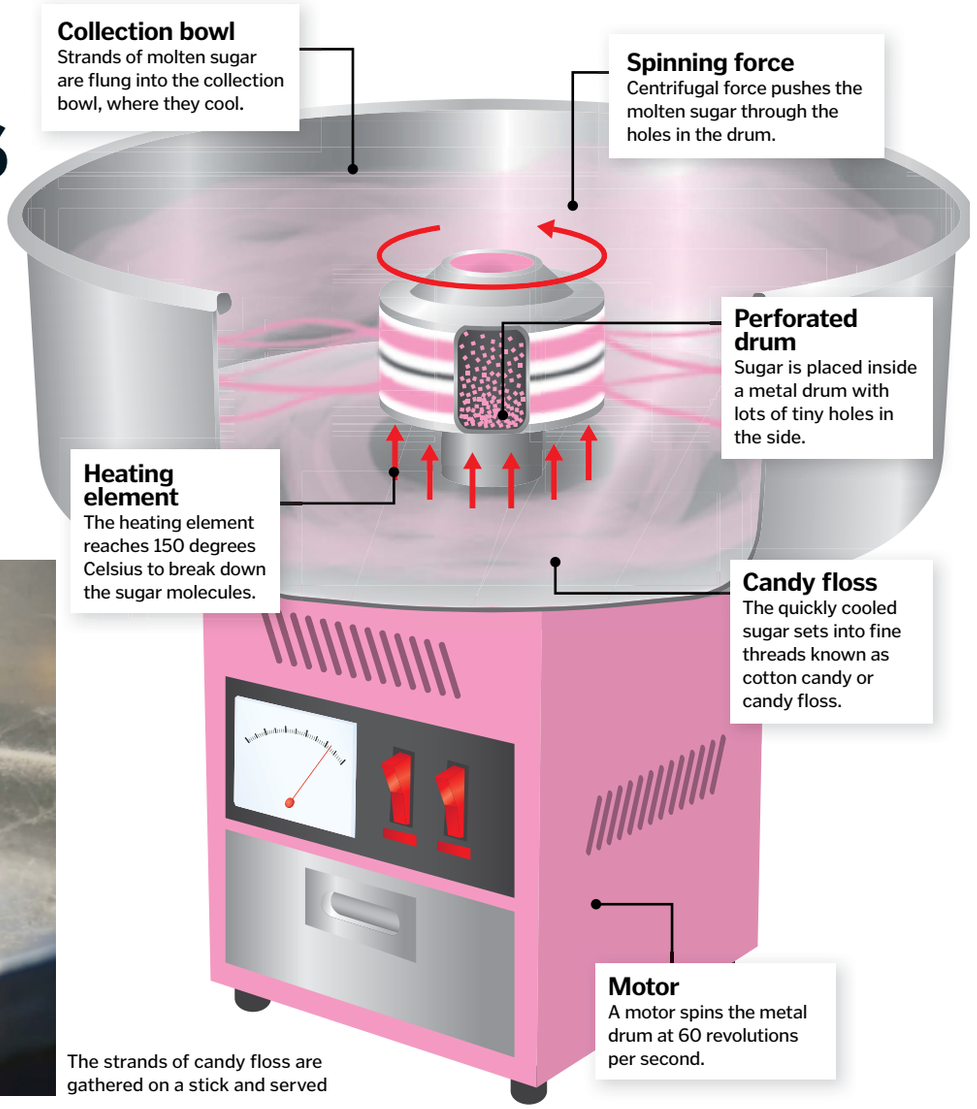
How do candy floss machines work?

Find out how these clever contraptions spin sugar into a delicious sweet treat

The strands of candy floss are gathered on a stick and served



How is frosted glass made?

Discover the processes that transform a clear window into a private screen

Frosted glass is commonly found in bathrooms, medical rooms and other areas that require privacy. The rough, translucent glass still allows light to pass through but blurs anything that's inside.

There are two main ways to achieve this. Sandblasting coats a glass surface with grit, which causes light that travels through the glass to scatter, making it translucent rather than transparent. Another similar method is to use a magnesium sulphate spray, which is applied to the glass and crystallises as it dries, making the surface blurry.

The other process is acid etching and is generally used for decorative work. This method uses an etching liquid – a solution containing an acid – to dissolve the surface of the glass. Stencils made from vinyl films or wax can also be used to protect some areas of the glass from etching, helping create intricate patterns.

Sandcarving is a more complicated form of sandblasting, used for art rather than functionality. It gives the glass a 3D appearance and is commonly used on light bulbs, award trophies and cabinets.

Glass frosting is especially useful when curtains or blinds would make a room too dark

How does pressure cooking work?

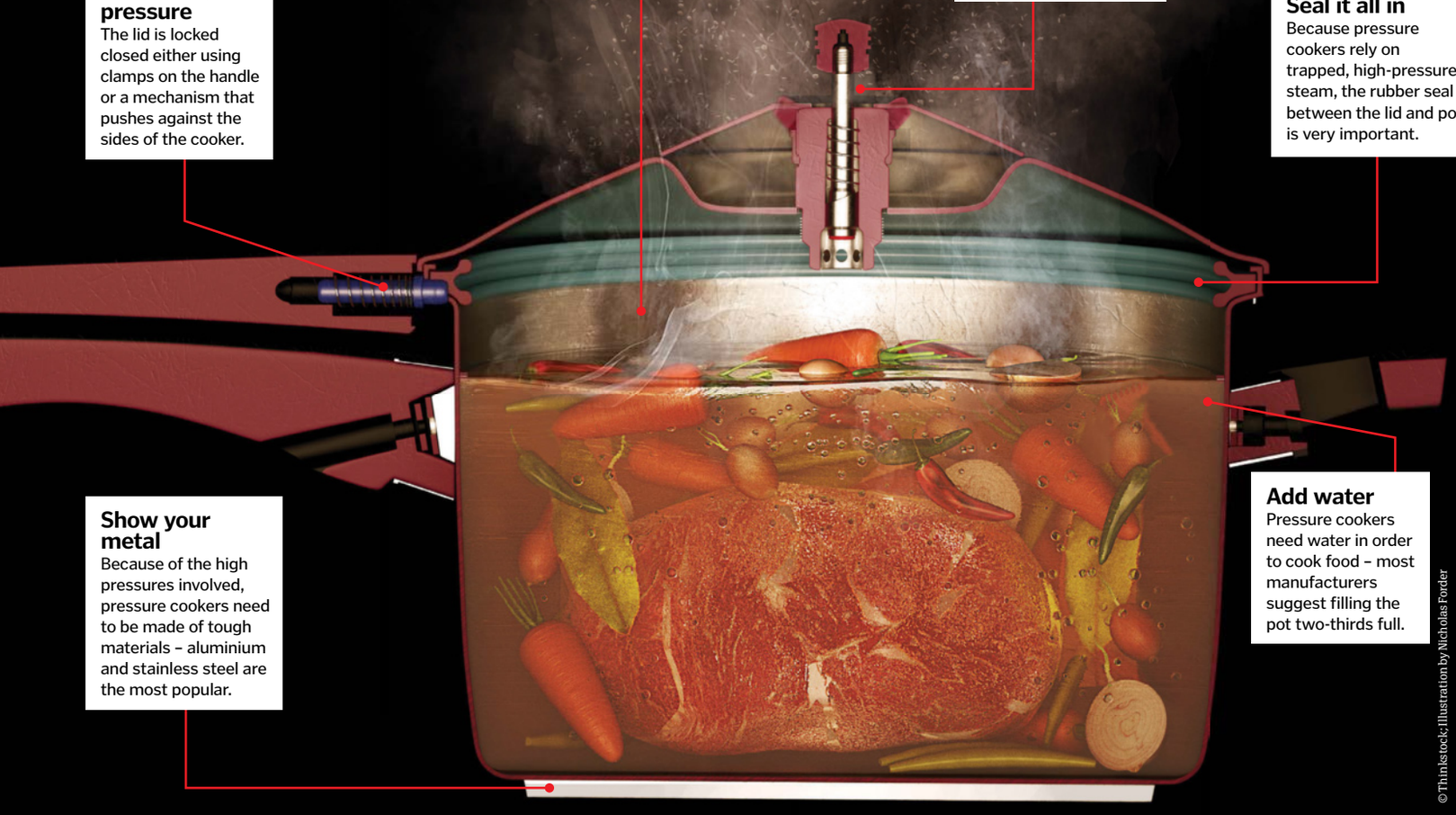
The airtight tech that speeds up cooking while using less energy

At first glance, a pressure cooker looks like any other pot, except for one difference – the lid locks in place. And this gives us a clue to how it can cook food so quickly. If you heat a traditional lidded pot of water on a stovetop, the highest temperature the water will ever reach will be 100 degrees Celsius. As it approaches this temperature, bonds between water molecules begin to break, turning the water into steam, which rises out of the pot. But pressure cookers use a series of clamps and bolts, along with a rubber O-ring, to seal the lid firmly to the pot, holding onto the steam and the hot water. With nowhere to go, air and water pressure build up inside the cooker, which in turn makes it harder for the water to boil. In fact, inside a pressure cooker, water has to reach 121 degrees Celsius before it can turn to steam, and this higher temperature reduces the cooking time. A safety valve in the lid regulates the pressure in the cooker, so that it can't eventually get so pressurised that it explodes! The valve automatically opens if the pressure increases beyond what is needed to maintain the cooking temperature to ensure your safety.

When the pressure gets too high, a valve on the lid releases some steam

The secret to high-speed cooking

Pressure cookers combine hot water and steam to cook food



Turn up the heat

Inside a pressure cooker, the high pressure increases the boiling point of water to beyond 100°C, which makes food cook quicker.

Blow some steam

Steam and water is usually sealed inside the pot, but a spring-loaded safety valve lets steam escape if pressures get too high.

Handle the pressure

The lid is locked closed either using clamps on the handle or a mechanism that pushes against the sides of the cooker.

Seal it all in

Because pressure cookers rely on trapped, high-pressure steam, the rubber seal between the lid and pot is very important.

Show your metal

Because of the high pressures involved, pressure cookers need to be made of tough materials – aluminium and stainless steel are the most popular.

Add water

Pressure cookers need water in order to cook food – most manufacturers suggest filling the pot two-thirds full.

Smile detection makes it easy to take the perfect portrait or selfie

What is smile detection?

Discover how some cameras know when you're saying the magic word – cheese!

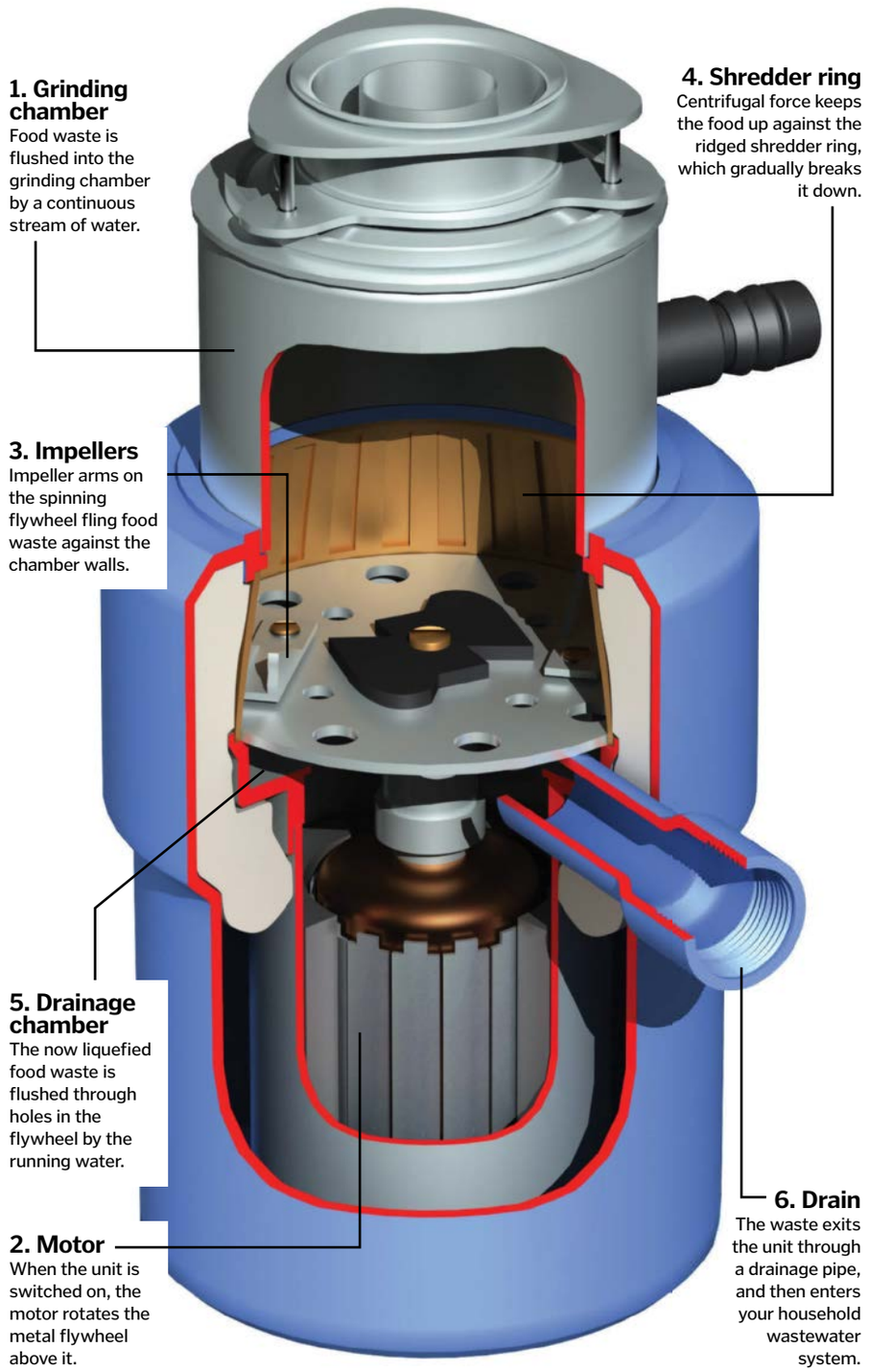
Capturing a lovely photo only to realise that your subject wasn't pulling their best cheesy grin can be frustrating, but some modern digital cameras and camera apps have now solved the problem. Equipped with smile detection, they can recognise when someone grins at the camera, and automatically take a photo of the happy moment.

For this clever feature to work, the camera must first locate the subject's face. A mathematical algorithm looks for a pair of eyes, a nose, eyebrows and lips by identifying the areas of contrast created by their shadows. If the layout of these features matches that of a typical face then the camera will lock on to them and continue to track them. To detect a smile, the algorithm will then look for areas of contrast created by narrowed eyes, visible teeth, an upturned mouth and raised cheeks. If all or some of these characteristics are identified then the camera will assume that the subject is smiling, and quickly take a photo before the moment has passed.

How do garbage disposal units work?

No blades are needed to get rid of your unwanted leftovers

These units are usually fitted beneath the kitchen sink to make food disposal simpler



1. Grinding chamber
Food waste is flushed into the grinding chamber by a continuous stream of water.

4. Shredder ring
Centrifugal force keeps the food up against the ridged shredder ring, which gradually breaks it down.

3. Impellers
Impeller arms on the spinning flywheel fling food waste against the chamber walls.

5. Drainage chamber
The now liquefied food waste is flushed through holes in the flywheel by the running water.

2. Motor
When the unit is switched on, the motor rotates the metal flywheel above it.

6. Drain
The waste exits the unit through a drainage pipe, and then enters your household wastewater system.

Xbox One S Teardown

Take a look inside the new, slimmer Xbox console

Gamers have just been given an upgrade with the release of the Xbox One S – a new, more powerful version of Microsoft's Xbox One. There are extra features packed into a smaller box, meaning gamers will be able to enjoy 4K video and HDR gaming for the first time on an Xbox.

While the console isn't getting a proper power upgrade (that will come with the release of Project Scorpio in 2017), it has been equipped with a new HDMI 2.0a port. It is this addition that will enable gamers to watch Ultra-HD Blu-rays and stream in 4K. Plus, the new High Dynamic Range technology (or HDR) increases the contrast ratio between light and dark colours, making games brighter and more immersive.

Of course, all of this has been fitted into a console that is 40 per cent smaller than the standard Xbox One. Even more impressively, the power brick, which previously had to be plugged into the back of the Xbox and trailed across the floor, is now integrated into the console itself. There are new storage options, too – you can pick up the console in 500GB, 1TB or 2TB configurations.

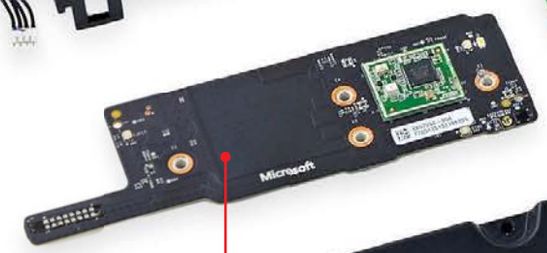
The refreshed design continues on the outside of the console, too. The power button, which was touch-sensitive on the Xbox One (and became annoying for those who had inquisitive dogs with wet noses), is now a physical button. There is also an infrared blaster on the front to make switching on all your devices at once more straightforward. For those who weren't sure about investing in an Xbox One in 2013, now might be the time to take the plunge.

The casing
The body of the Xbox One S is 40 per cent smaller than that of the original Xbox One.

Cooling system
This giant fan helps to keep the Xbox One S cool, which is important when so much power is being used.

Inside the Xbox One S

How does it pack its power into such a small space?



Front panel
This board houses important controls like the infrared blaster and the Bluetooth module, which lets you connect your controllers.

The new console can be used horizontally or vertically, but only early buyers will get a stand in the box

Optical drive
The new Xbox One supports 4K, so this new optical drive will also play UHD Blu-rays.

Anti-rattle bumpers
Inside this casing are two rubber bumpers, which are likely to be there to prevent the optical drive from rattling as it spins.

The new controller features a grippy surface on the back to help gamers stay in control

Ports
On the back you'll find all the same ports as the standard Xbox One, except for the Kinect port – you'll need an adapter for that.

Hard drive
The new Xbox One S offers a 2TB storage option, along with 1TB and 500GB models.

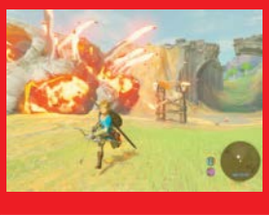
Motherboard
The new chips on the motherboard include a power-boosted GPU (Graphics Processing Unit), which means the Xbox One now supports HDR.

Power supply
The power supply is housed inside the Xbox One's casing for the first time.

Wi-Fi board
This module allows access to a Wi-Fi network, enabling users to play against friends online and connect to video streaming services.

"The Xbox One S allows gamers to watch Ultra-HD Blu-rays for the first time"

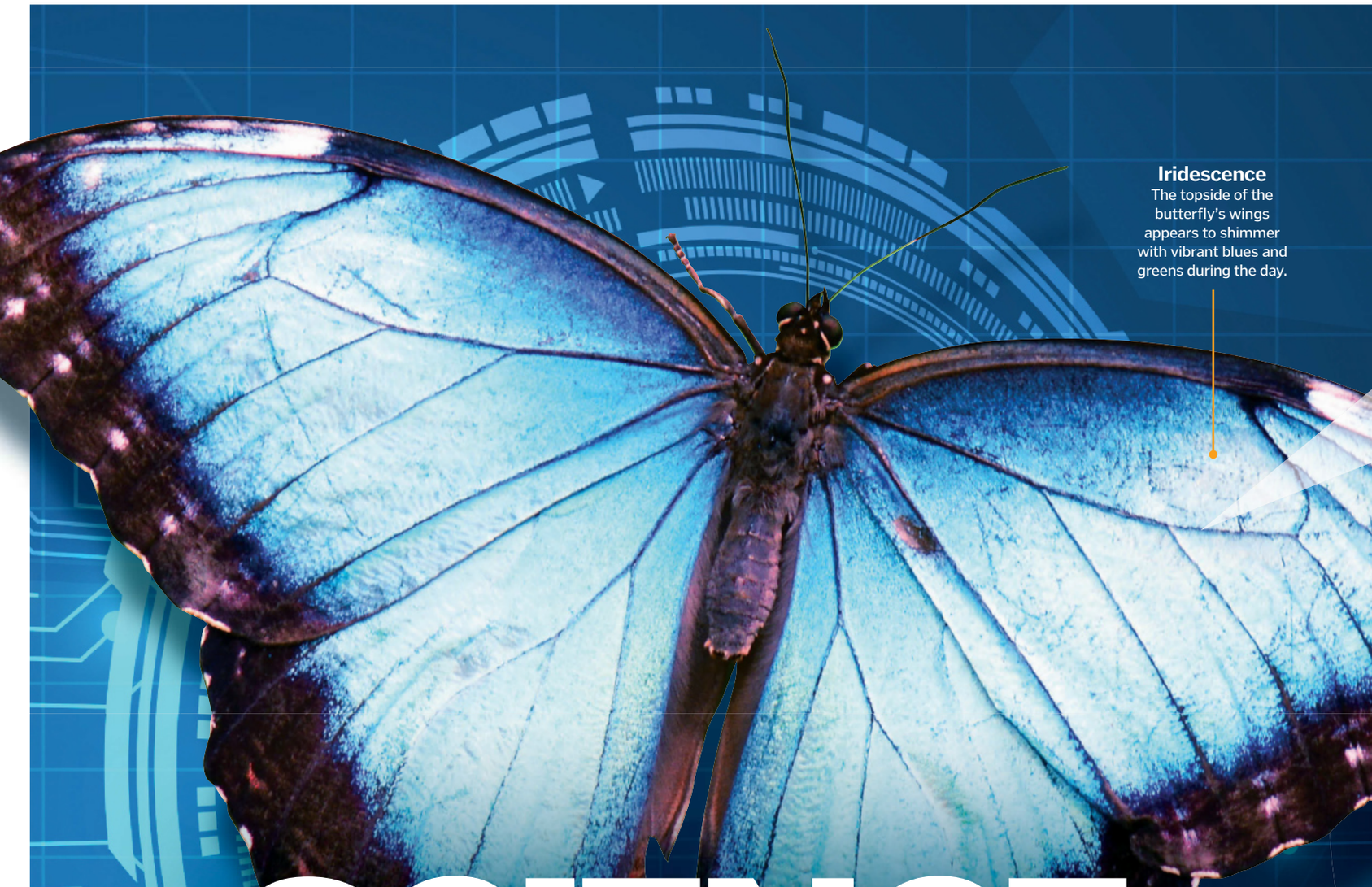
Next-gen consoles



Nintendo NX
Nintendo will release a new console, codenamed NX, in March 2017. Details are scarce, but it will be more powerful than the Wii U.

Project Scorpio
A new Xbox is in the works at Microsoft, codenamed Project Scorpio. It will have six teraflops of computing capability, for true 4K gaming.

PS4 Pro
The PS4 Pro is more than just a powered-up PS4. It supports 4K gaming and HDR out of the box, so new games will look and play better than ever.



Iridescence
The topside of the butterfly's wings appears to shimmer with vibrant blues and greens during the day.

SCIENCE INSPIRED BY NATURE

The incredible innovations we have borrowed from animals and plants

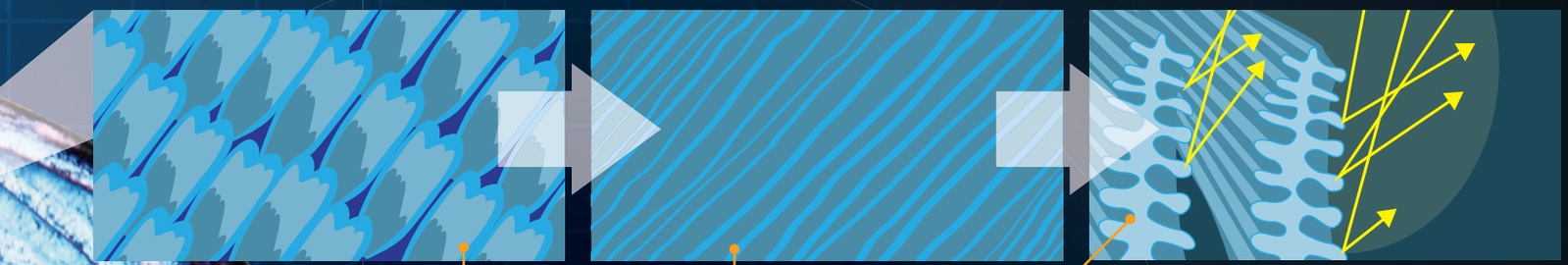
Biological organisms on Earth have spent billions of years evolving to become masters of their environments, capable of overcoming obstacles in ingenious ways to survive in a competitive world. For example, certain parasitic wasps use their long, tubular egg-depositing organs to bore through several centimetres of solid wood, despite their inability to supply much downward force.

They achieve this by sliding the two halves of the ovipositor back and forth to penetrate further into the wood, while causing little disturbance to the surrounding area. This mechanism is quite different to drills currently used in construction and neurosurgery, but scientists have taken inspiration from this natural technique to design innovative tools, such as new steerable medical probes.

Resourceful methods such as this are abundant in the natural world, and engineers in many fields have begun to appreciate the advantages that mimicking plants and animals can bring. From construction to combat, biomimicry is helping us to discover new ways to solve old problems, and opening doors to revolutionary technologies that can push our own evolution one step further.

Natural colour

How a butterfly inspired a full-colour e-reader



Scales

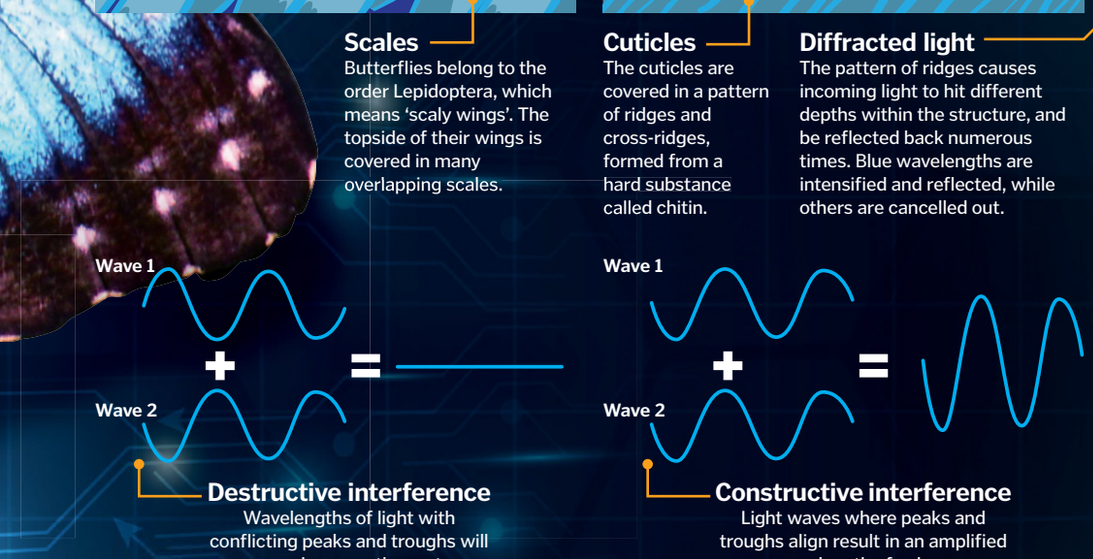
Butterflies belong to the order Lepidoptera, which means 'scaly wings'. The topside of their wings is covered in many overlapping scales.

Cuticles

The cuticles are covered in a pattern of ridges and cross-ridges, formed from a hard substance called chitin.

Diffracted light

The pattern of ridges causes incoming light to hit different depths within the structure, and be reflected back numerous times. Blue wavelengths are intensified and reflected, while others are cancelled out.



Destructive interference

Wavelengths of light with conflicting peaks and troughs will cancel one another out.

Constructive interference

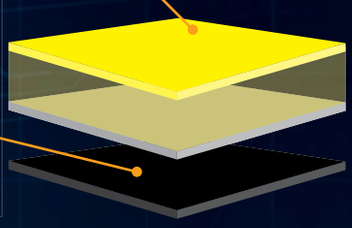
Light waves where peaks and troughs align result in an amplified wavelength of colour.

Projected light

External light penetrates through the glass, and wavelengths able to escape again are projected, determining the colour.

Adjustable panels

The size of the gaps between the panels can be adjusted, allowing only the wavelengths that directly match the size of the gap to be reflected.



A multitude of colours

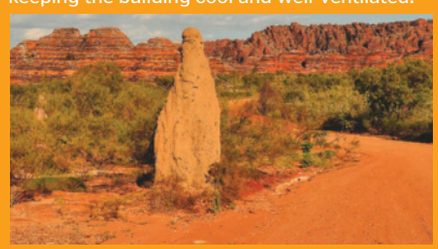
The plate gaps can be altered 1,000 times a second, allowing combinations of colours to be reflected. This enables the screen to display any colour across the visible spectrum.

Construction tips from termites

When you think of the world's greatest architects, termites probably don't spring to mind. But these creatures are capable of building huge cities complete with storage chambers, ventilation shafts and gardens, all in one mound of dirt.

The intricate network of tunnels inside the mound takes advantage of convection currents – where warm air rises and colder, denser air sinks – to maintain a stable temperature, permitting the termites to farm their primary fungal food source all year round.

This miraculous feat inspired architect Mick Pearce to design a sustainable building that is free of air-conditioning and heating units, yet remains a comfortable temperature year-round. Using the principles of the termites, the building incorporated a series of ducts and chimneys that carried heat upwards and outwards, keeping the building cool and well-ventilated.



Termites build complex structures to maintain stable temperatures in varying external heat

Inspiring animals

Other tech and engineering feats inspired by animals

Improving high-speed rail

Japan's 500-series Shinkansen bullet trains could travel at up to 300 kilometres per hour, but created a 'tunnel boom'. Taking inspiration from the streamlined kingfisher beak, the nose was re-engineered, so newer models are quieter, faster and energy efficient.

Reducing drag

Sharks are powerful predators, partly thanks to their incredible speed – some can swim at over 50 kilometres per hour! Scientists believe the bony scales covering their skin reduce drag as they move through water, and have used this idea to create more hydrodynamic boats.

Camouflaged clothing

Cephalopods are able to change the appearance of their skin to hide from predators or stalk unsuspecting prey. They use muscle contractions to expose varying pigments of colour to match their background. This has been mimicked by engineers and could be used in 'smart clothing'.

Artificial photosynthesis

Converting harmful gases to eco-friendly fuel with a man-made leaf

Plants have been sustaining animal life for hundreds of millions of years. By absorbing carbon dioxide, water and energy from the Sun, they produce oxygen and energy in the form of carbohydrates. Scientists have now developed an artificial leaf capable of doing the same. In fact, the artificial leaf is up to ten times more efficient at capturing solar energy than its natural counterparts. It uses catalysts to split water into oxygen and hydrogen. Specialised bacteria are then able to convert the hydrogen, along with the carbon dioxide, into liquid fuels.

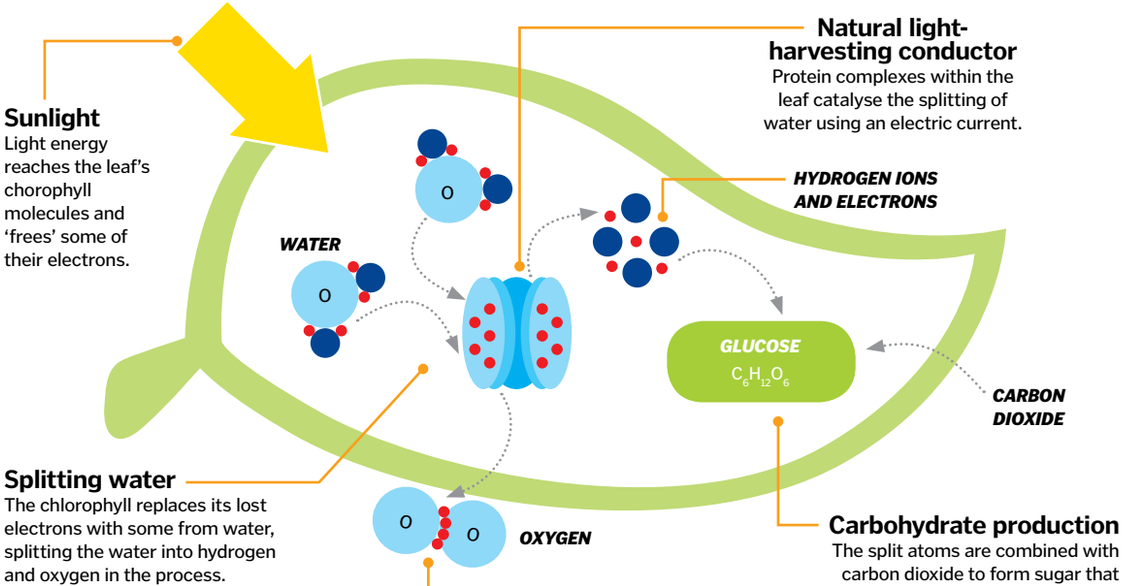
This revolutionary technology, capable of generating liquid fuel with no carbon footprint, could be an important tool in reducing our carbon dioxide emissions.

"The artificial leaf is up to ten times more efficient at capturing solar energy than its natural counterparts"

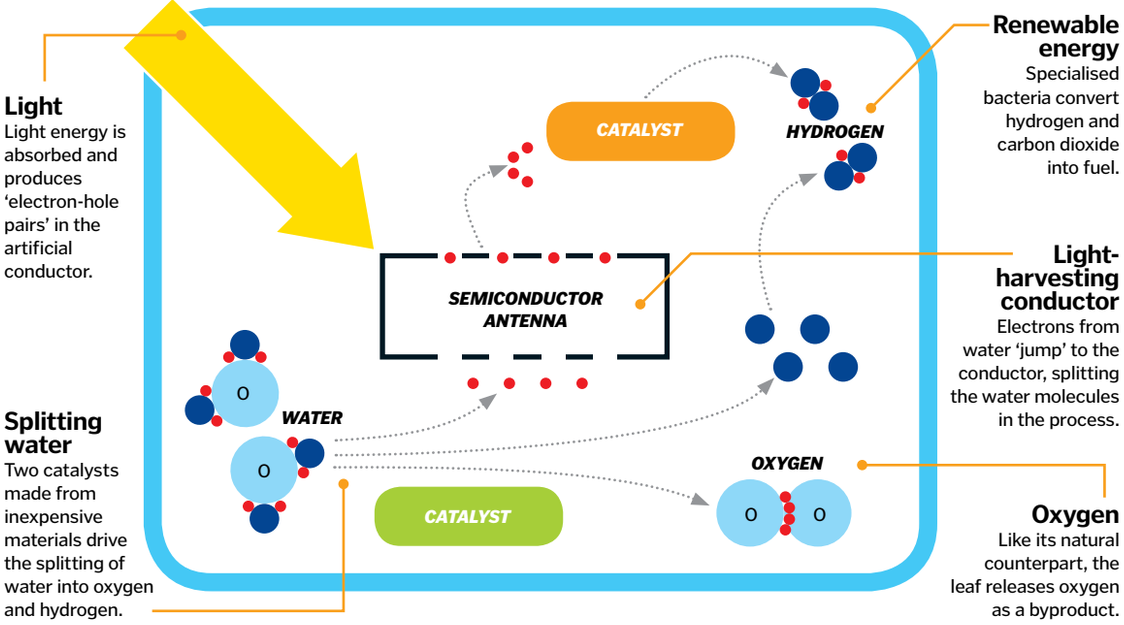
Harnessing plant power

Whether they're made in a forest or a lab, both types of leaf operate in much the same way

NATURAL PHOTOSYNTHESIS



ARTIFICIAL PHOTOSYNTHESIS



Improving efficiency

How animals have led to scientific discoveries

Velcro adhesives

Not having to tie your shoelaces was a great thing in the early school days, and we have biomimicry to thank for it. The invention was conceived after an engineer noticed how well the tiny hooks on plant burrs gripped to his dog's fur.

Superior wind turbines

Humpback whales are amazingly dextrous animals, despite their mammoth size, due to large bumps – known as tubercles – found on the edges of their flippers. This feature improves lift and reduces drag as the whale performs tricky manoeuvres, and could be incorporated into fans, aeroplanes and wind turbines.

Harvesting water in the desert

The Namib Desert is one of the driest habitats in the world, but darkling beetles have managed to survive there – by sticking their rear ends in the air and collecting water vapour. Researchers have found microscopic grooves on the beetle's forewings that help to funnel water towards their mouths. These grooves are now being incorporated into designs used for water collection devices.

Mimicking intelligence

As well as being the source of our creativity, the structure of the brain is an inspiring innovation

The human brain is often said to be the most complicated object in the known universe, encompassing around 100 billion neurons arranged in a massive network, where each neuron is connected to approximately 10,000 others. Our superior aptitude to learn, interpret and think creatively has helped us to cure diseases, place humans on the Moon, and develop helpful computer programs that surround us in our everyday lives.

Computer power and capability has improved massively in the past few decades, and today a computer can solve a mathematical problem almost instantly, much faster than the human brain. Shops, schools, hospitals and laboratories all use these machines as an integral part of their working systems.

These tools are highly capable at certain tasks but cannot yet match the brain's most incredible attributes. Our sophisticated organ can interpret and process sensory data on an unparalleled scale; we can stand on the beach in the summer listening to the waves, watching the birds and feeling the heat of the Sun, and compose all of that data into a cohesive setting. We can also learn and adapt from experiences.

Both attributes would be highly advantageous for a computer program to harness. An algorithm has recently been developed that is capable of analysing images from MRI scans to diagnose tumours or anomalies, and developers of artificial neural networks have also taken inspiration from the brain to produce programs that are capable of learning by practice.

These programs still have a long way to go to match the power of the world's greatest supercomputers sat snugly in our heads, but by using the brain as a model, we are growing ever closer to inventing a truly powerful artificial intelligence.

Dharmendra S. Modha presents a brain-inspired supercomputer system containing 16 TrueNorth chips

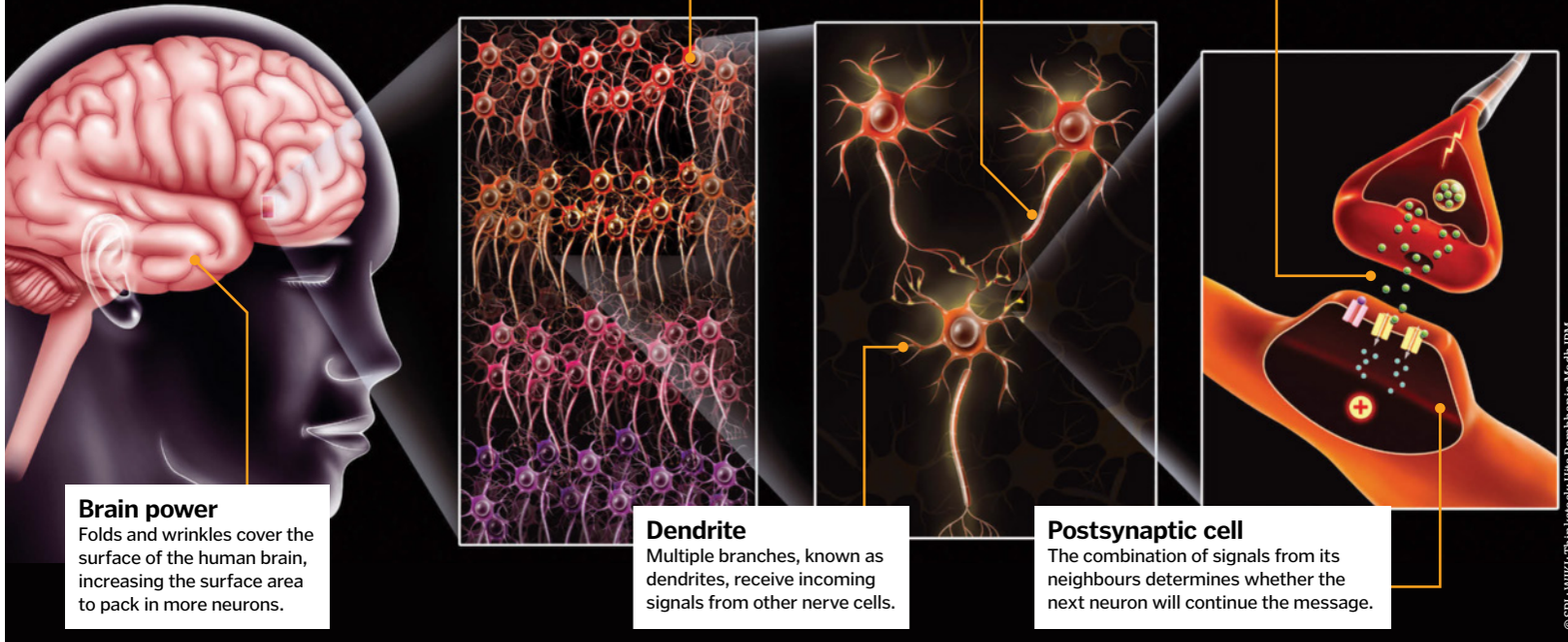
Neurons on a computer chip

Researchers at IBM have turned to the architecture of our brains to develop the TrueNorth computer chip, a brain-inspired processor with 1 million artificial neurons and 256 million artificial synapses. By mimicking the modular and flexible design of the brain, the researchers developed a scaled-down neurosynaptic network with integrated computation and memory, and considerable processing power. The programming language unique to this machine is in the process of being made commercially available, so we may have brain-like computers controlling our smartphones in the near future.

"We may have brain-like computers controlling our smartphones"

The human brain

Our brains are immense networks of nerve cells that fire electrical signals to exchange information



Neural network
The neurons interact by transmitting electrical currents, and can receive information from multiple sources.

Axon
The axon carries information away from the cell body towards the synapse.

Synapse
Chemical messengers known as neurotransmitters are released and traverse the gap between neurons.

Brain power
Folds and wrinkles cover the surface of the human brain, increasing the surface area to pack in more neurons.

Dendrite
Multiple branches, known as dendrites, receive incoming signals from other nerve cells.

Postsynaptic cell
The combination of signals from its neighbours determines whether the next neuron will continue the message.

Robotic animals

Constructing machines in nature's image

When we imagine a dystopian future, it's almost always filled with robotic assistants. We do not have to stretch our imaginations too far to think of ways that machines could help us: they could play a role in warfare, join rescue teams, or carry our shopping. Today, many scientists are dedicated to constructing machines that can fill these roles – and finding the optimal designs was easy, as nature had already provided the templates.

Animals have adapted to excel in every environment on the planet. Species exist in extreme temperatures, reside on mountaintops, and live in the depths of the ocean. Engineers hope to capture their natural affinity for these locations by copying their specialised features and characteristics. Imitating animal anatomy also allows us to gift robots with admirable abilities, such as incredible speed or the power of flight.

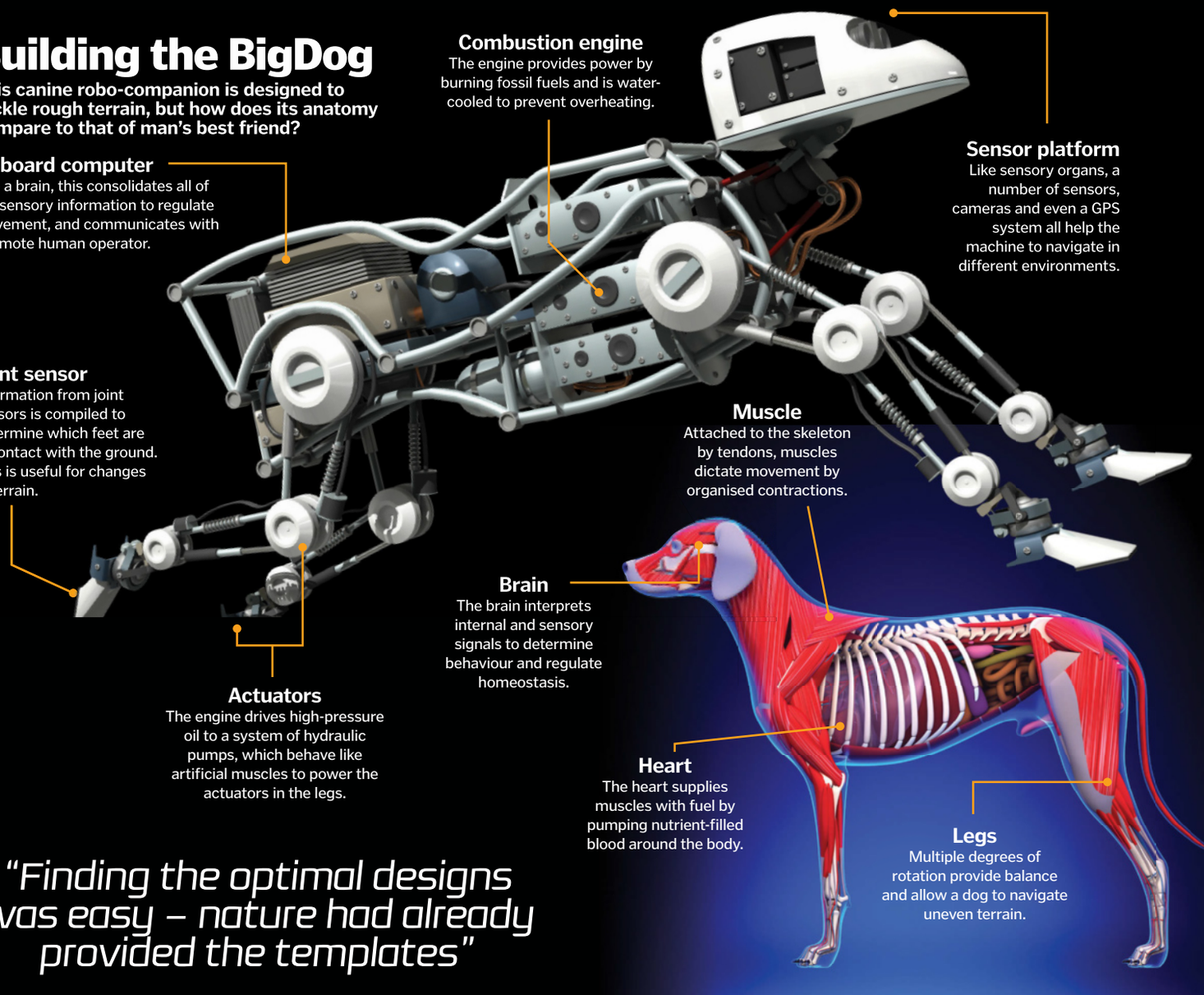
Huge inroads have already been made towards building these machines. A cheetah – the fastest land animal on Earth – achieves great speeds using its flexible spine. The animal's robotic counterpart, developed by Boston Dynamics, flexes its back in a similar way to run at over 45 kilometres per hour. Meanwhile, the giant AlphaDog can carry up to 180 kilograms over large distances, the robotic equivalent of a reliable pack mule.

From the tiny RoboBees that could pollinate crops or monitor traffic, to the ape-like android that might even help us to explore Mars, robotic animals of all sizes are really starting to show their potential, and the applications appear to be endless.

Boston Dynamics' BigDog is designed to help carry soldiers' equipment autonomously over complex terrain

Building the BigDog

This canine robo-companion is designed to tackle rough terrain, but how does its anatomy compare to that of man's best friend?



Combustion engine
The engine provides power by burning fossil fuels and is water-cooled to prevent overheating.

Onboard computer
Like a brain, this consolidates all of the sensory information to regulate movement, and communicates with a remote human operator.

Sensor platform
Like sensory organs, a number of sensors, cameras and even a GPS system all help the machine to navigate in different environments.

Joint sensor
Information from joint sensors is compiled to determine which feet are in contact with the ground. This is useful for changes in terrain.

Muscle
Attached to the skeleton by tendons, muscles dictate movement by organised contractions.

Brain
The brain interprets internal and sensory signals to determine behaviour and regulate homeostasis.

Actuators
The engine drives high-pressure oil to a system of hydraulic pumps, which behave like artificial muscles to power the actuators in the legs.

Heart
The heart supplies muscles with fuel by pumping nutrient-filled blood around the body.

Legs
Multiple degrees of rotation provide balance and allow a dog to navigate uneven terrain.

"Finding the optimal designs was easy – nature had already provided the templates"

Tabbot

A species of spider in Morocco has mastered a fancy party trick: cartwheeling. The spider, known locally as 'tabacha', flips up and down sand dunes to escape predators, and this athletic movement formed the blueprint for its robotic cousin, Tabbot. This machine is capable of both walking and somersaulting, and has the potential to traverse deserts both at home on Earth and away on Mars.

RoboClam

The Atlantic razor clam is a large mollusc capable of digging at incredible speeds that human drills cannot match. It achieves this by forcefully opening and closing the shells on its body to turn surrounding soil into liquid, reducing the resistance faced by the clam as it burrows further into the earth – and all at a low energy cost. Engineers have designed a mechanical device based on these principles that could be used to anchor submarines in the future.

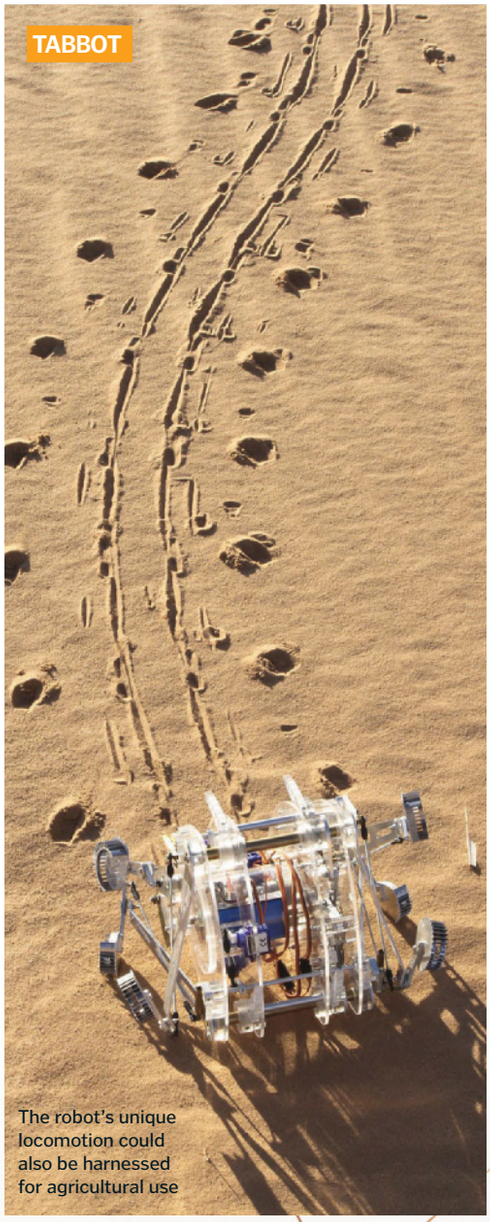
Anti-mine lobsters

Underwater mines pose a serious threat to military submersibles, so the US navy has envisaged deploying robots to scout the sea floor in pursuit of these hidden dangers. In order to develop a machine capable of effectively scouring the depths, they designed a robotic lobster – with the aim of capturing the natural version's efficient, wave-like motion – and attached mine-detecting sensors to the frame.

Rescue cockroaches

Cockroaches are typically regarded as disgusting nuisances that are notoriously difficult to kill. Researchers found their exoskeletons could withstand a force of 300 times their body weight while still moving, and that they could continue to scuttle rapidly in extremely tight spaces. Their flexible design led to the inception of CRAM – or 'compressible robot with articulated mechanisms' – that has been constructed in the cockroach's image. The capability of this machine to navigate through small gaps has made it an able candidate as a rescue robot, so perhaps in the future the sight of a cockroach will bring a sigh of relief rather than a scream of terror.

TABBOT



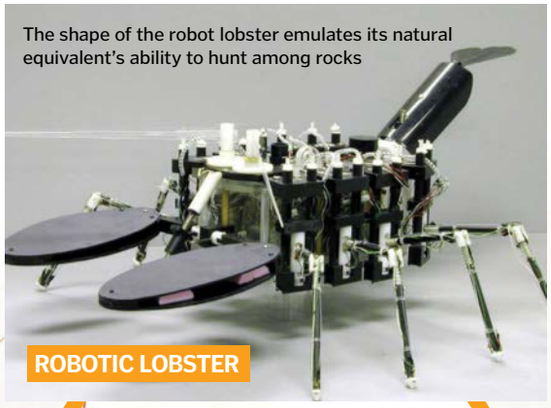
The robot's unique locomotion could also be harnessed for agricultural use

ROBOCLAM

Deep submersibles would benefit from a lightweight, reversible anchoring mechanism

"Perhaps the sight of a cockroach will bring a sigh of relief"

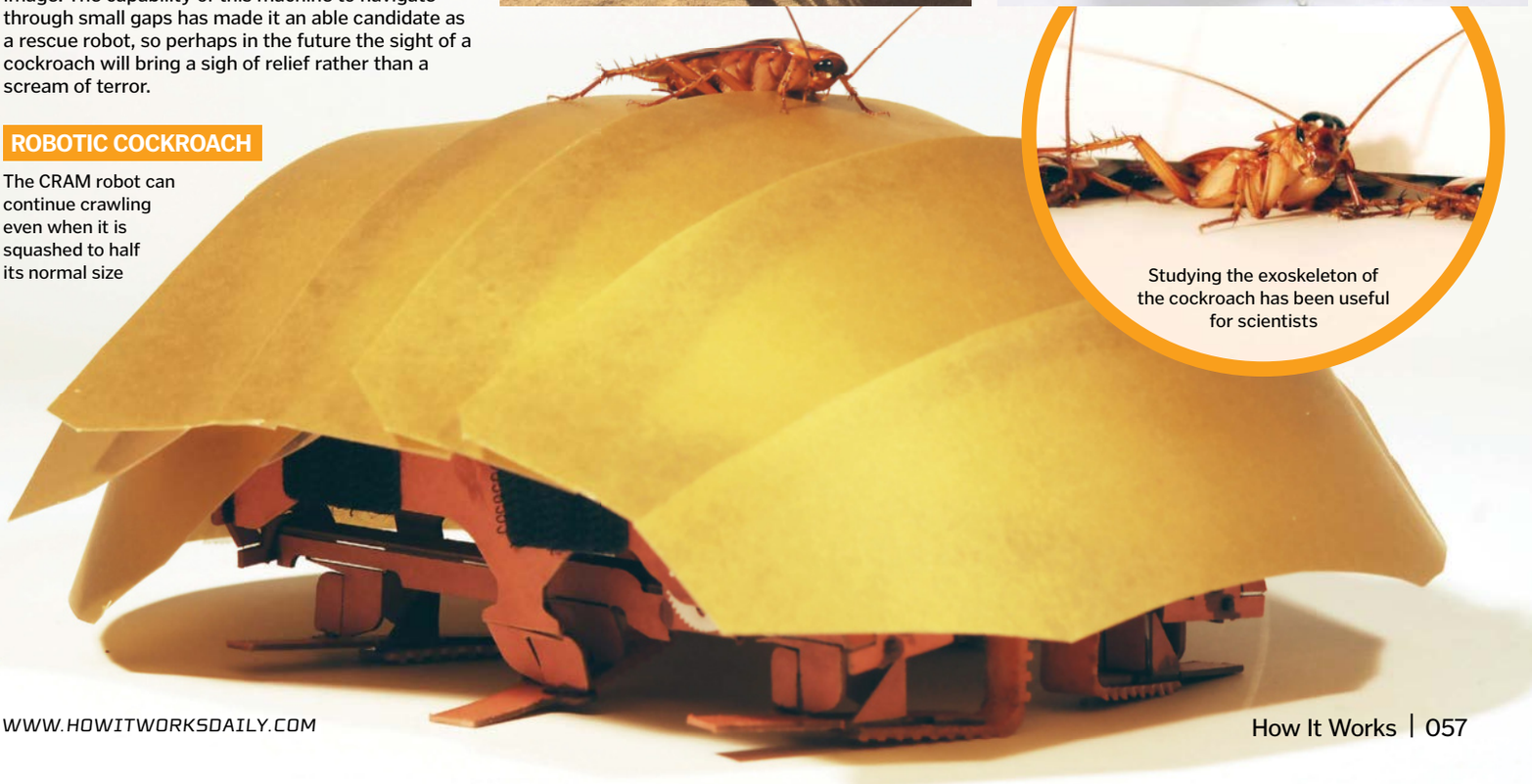
The shape of the robot lobster emulates its natural equivalent's ability to hunt among rocks



ROBOTIC LOBSTER

ROBOTIC COCKROACH

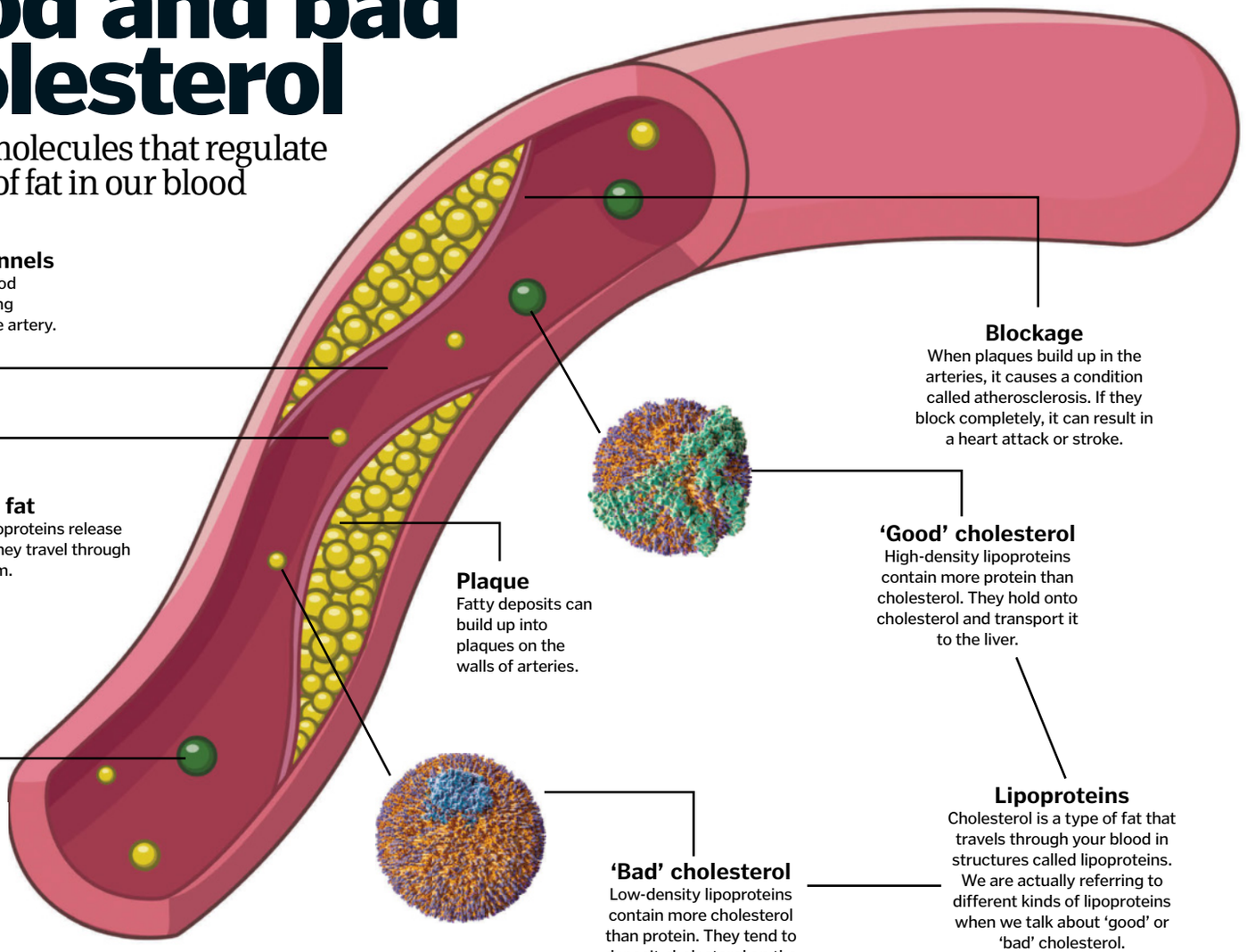
The CRAM robot can continue crawling even when it is squashed to half its normal size



Studying the exoskeleton of the cockroach has been useful for scientists

Good and bad cholesterol

Meet the molecules that regulate the levels of fat in our blood



Narrowed channels
Plaques increase blood pressure by restricting available space in the artery.

Blockage
When plaques build up in the arteries, it causes a condition called atherosclerosis. If they block completely, it can result in a heart attack or stroke.

Depositing fat
Low-density lipoproteins release cholesterol as they travel through the blood stream.

‘Good’ cholesterol
High-density lipoproteins contain more protein than cholesterol. They hold onto cholesterol and transport it to the liver.

Plaque
Fatty deposits can build up into plaques on the walls of arteries.

Lipoproteins
Cholesterol is a type of fat that travels through your blood in structures called lipoproteins. We are actually referring to different kinds of lipoproteins when we talk about ‘good’ or ‘bad’ cholesterol.

Removing fat
Good cholesterol, or high density lipoproteins, help to remove fat from the bloodstream by transporting it to the liver, where it is broken down.

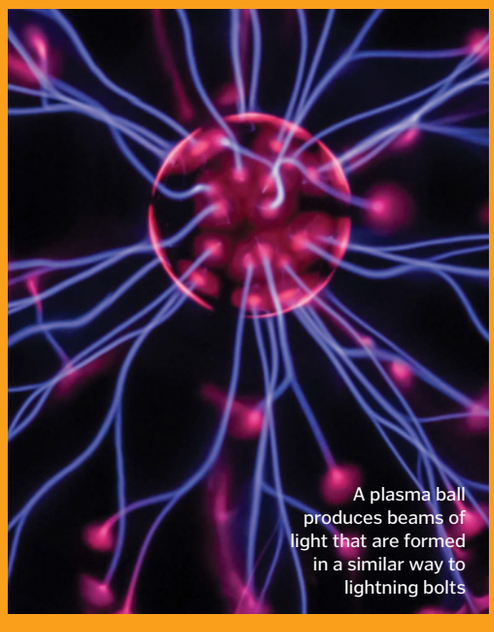
‘Bad’ cholesterol
Low-density lipoproteins contain more cholesterol than protein. They tend to deposit cholesterol on the walls of arteries as they travel through the blood.

What is plasma?

Discover the highly energised matter that powers life on Earth

We’re all familiar with solids, liquids and gases, which are three fundamental states of matter. But although it’s not as well known, there’s actually a fourth state that’s more common than all of the others – plasma. This state occurs when atoms of gas are packed with energy, transforming them into separate positively and negatively charged particles. Unlike gas, plasma is a great conductor of electricity and can respond to magnetic forces. It may sound strange, but we actually see these energetic particles every day here on Earth.

During a lightning storm, for example, plasma is responsible for the beams of light we see flashing down from the sky. The massive current moving through the air energises atoms and turns them into plasma particles, which bump into each other and release light. We also see plasma every time we look at the Sun. The high temperatures are constantly converting the Sun’s fuel – hydrogen and helium atoms – into positively charged ions and negatively charged electrons, making our local star the most concentrated body of plasma in the Solar System.



A plasma ball produces beams of light that are formed in a similar way to lightning bolts

Deodorant vs anti-perspirant

The science behind the sprays and roll-ons that rid your underarms of unwanted odour

Body odour is produced in many animals, but for humans it is generally considered an unpleasant stench – and most people choose to avoid it altogether by using deodorants or anti-perspirants. Sweat is produced by two different types of glands in our bodies. Eccrine glands are attached to hair follicles beneath the skin, covering most of the body. These are associated with the sweat we produce when we need to cool down, which mainly consists of water and electrolytes. Apocrine glands are found beneath the skin in areas like the hands, feet and underarms. These glands are associated with nervous perspiration, and produce sweat that contains proteins and fatty acids.

Sweat itself doesn't smell, but when the bacteria that live on our skin digest the proteins produced by apocrine glands, they produce some fatty acids. The unwanted aroma is often at its most pungent in the armpits, due to this area being warm and moist, conditions in which bacteria thrive.

Both deodorants and anti-perspirants are used to counteract this undesirable scent, but they work in different ways. Deodorants mask the smell and work against it by using anti-microbial agents such as triclosan to kill the bacteria. They make your underarm skin too acidic to harbour this type of bacteria so no body odour is created. Deodorants do nothing to stop you sweating though, which is where anti-perspirants come in.

In an attempt to tackle the problem at its source, anti-perspirants block your sweat glands. These products contain aluminium ions, which can be taken up by the cells lining the eccrine sweat gland ducts. As the aluminium ions enter the cell, they also bring water, causing the cells to swell. This effectively seals the ducts so sweat can't reach your skin for bacteria to feed on. The blocking of the glands is only temporary, and the time taken for you to start sweating again depends on the strength of the product, and who is wearing it.

Why do gym clothes smell?

Exercise is a healthy yet smelly business, but some sportswear gets much more pungent than others. Various studies have put different materials to the test, and found that synthetic fabrics like polyester are more prone to a post-workout pong than natural fibres like cotton. Clothes made from cotton absorb moisture, so sweat and the smelly compounds produced by bacteria get soaked up by the natural fibres, where our noses can't detect them. Polyester clothes don't absorb sweat, but instead trap the particles on the surface, where odour-producing bacteria can feast on them. Studies also found that some bacteria species seem to thrive on polyester clothes, but are less able to grow on cotton or wool.

If your gym bag is particularly pongy, try swapping your polyester workout clothes for cotton

Why do we sweat?

Perspiration is an essential bodily function to help us regulate our body temperature. We also sweat when we're anxious or stressed, but the purpose of this kind of perspiration is poorly understood. Some research suggests that the smell of a stranger's body odour can trigger the fight or flight response. This could be an evolutionary defence mechanism: if a nearby person is anxious because they think they're in danger, then you could also be at risk and your body prepares for action. Another study found that the smell of a family member's body odour helped reduce stress levels. Both these results suggest that these smells could prompt our emotional responses in different situations.

Another theory is that sweat may carry pheromones, which are common in the animal kingdom. Animals use these chemicals to communicate and change their behaviour, but as yet there is no direct evidence to suggest that humans have them.

Sweat plays an important role in regulating your body temperature

The human heartbeat

How one of your hardest-working muscles keeps your blood pumping

Your heart began to beat when you were a four-week-old foetus in the womb. Over the course of the average lifetime, it will beat over 2 billion times.

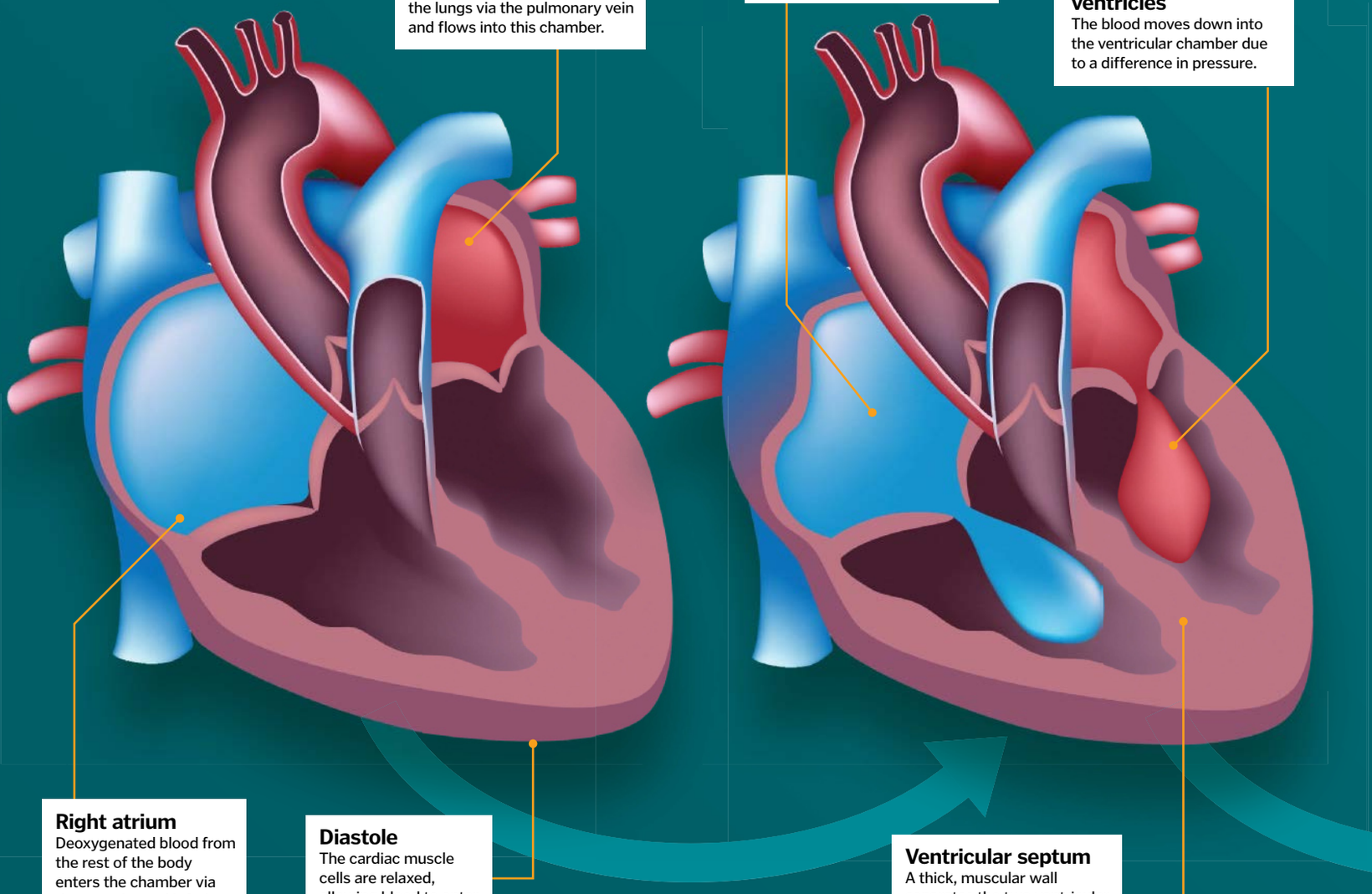
The heart is composed of four chambers separated into two sides. The right side receives deoxygenated blood from the body, and pumps it towards the lungs, where it picks up oxygen from the air you breathe. The oxygenated blood returns to the left side of the heart, where it is sent through the circulatory system, delivering oxygen and nutrients around the body.

The pumping action of the heart is coordinated by muscular contractions that are generated by electrical currents. These currents regularly trigger cardiac contractions known as systole. The upper chambers, or atria, which receive blood arriving at the heart, contract first. This forces blood to the lower, more muscular chambers, known as ventricles, which then contract to push blood out to the body. Following a brief stage where the heart tissue relaxes, known as diastole, the cycle begins again.

The heart consists of four chambers, separated into two sides

The cardiac cycle

A single heartbeat is a series of organised steps that maximise blood-pumping efficiency



Left atrium
Oxygenated blood arrives from the lungs via the pulmonary vein and flows into this chamber.

Atrial systole
The atria contract, decreasing in volume and squeezing blood through to the ventricles.

Blood enters the ventricles
The blood moves down into the ventricular chamber due to a difference in pressure.

Right atrium
Deoxygenated blood from the rest of the body enters the chamber via the superior and inferior vena cava.

Diastole
The cardiac muscle cells are relaxed, allowing blood to enter the ventricles freely.

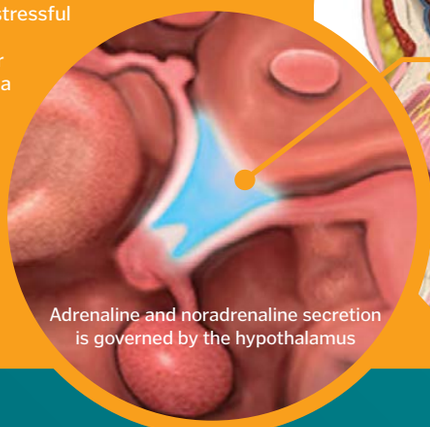
Ventricular septum
A thick, muscular wall separates the two ventricular chambers of the heart.

"Over the course of the average lifetime, the heart will beat over 2 billion times"

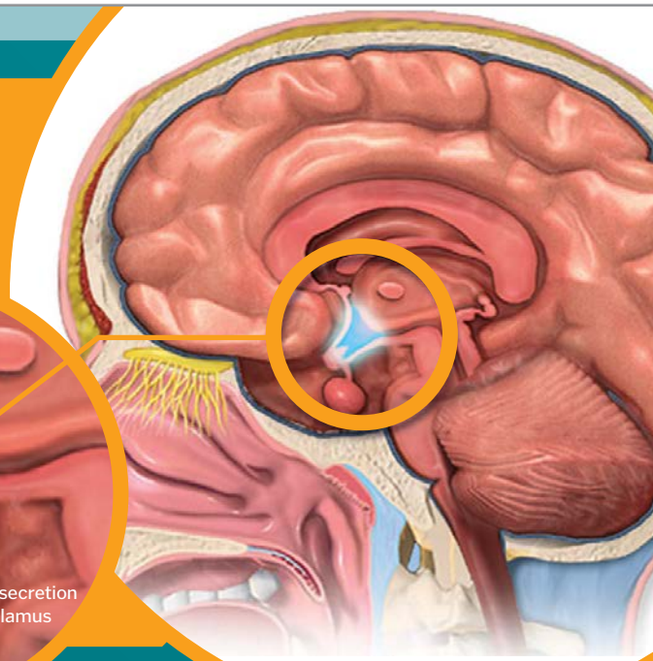
Fight or flight

A heartbeat begins at the sinoatrial node, a bundle of specialised cells in the right atrium. This acts as a natural pacemaker by generating an electrical current that moves throughout the heart, causing it to contract. When you are at rest, this happens between 60 to 100 times per minute on average. Under stressful situations however, such as an encounter with a predator, your brain will automatically trigger a 'fight or flight' response.

This results in the release of adrenaline and noradrenaline hormones that change the conductance of the sinoatrial node, increasing heart rate, and so providing the body with more available nutrients to either fight for survival or run for the hills.



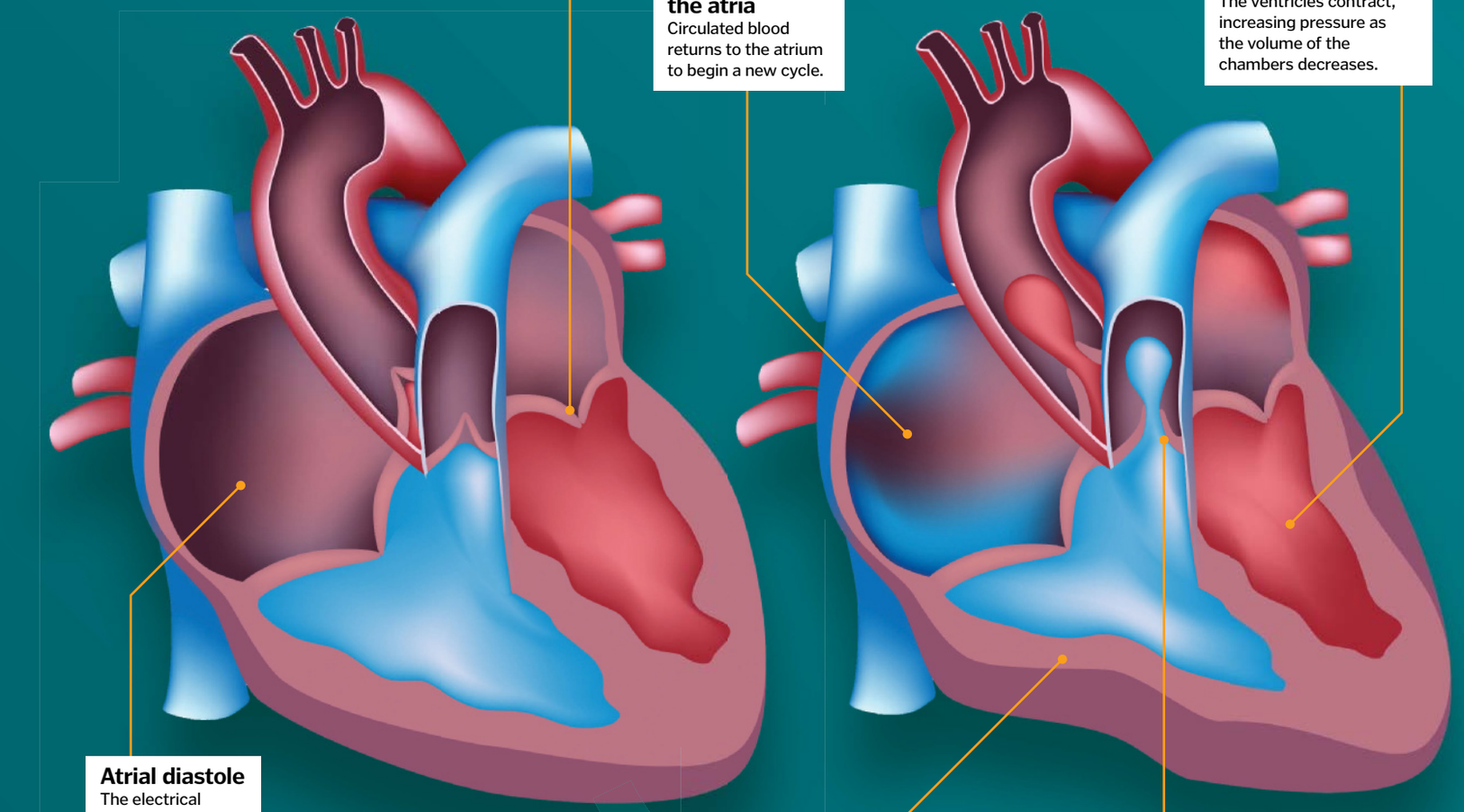
Adrenaline and noradrenaline secretion is governed by the hypothalamus



Closure of cuspid valves
The valves snap shut to prevent the blood flowing back into the atria.

Blood enters the atria
Circulated blood returns to the atrium to begin a new cycle.

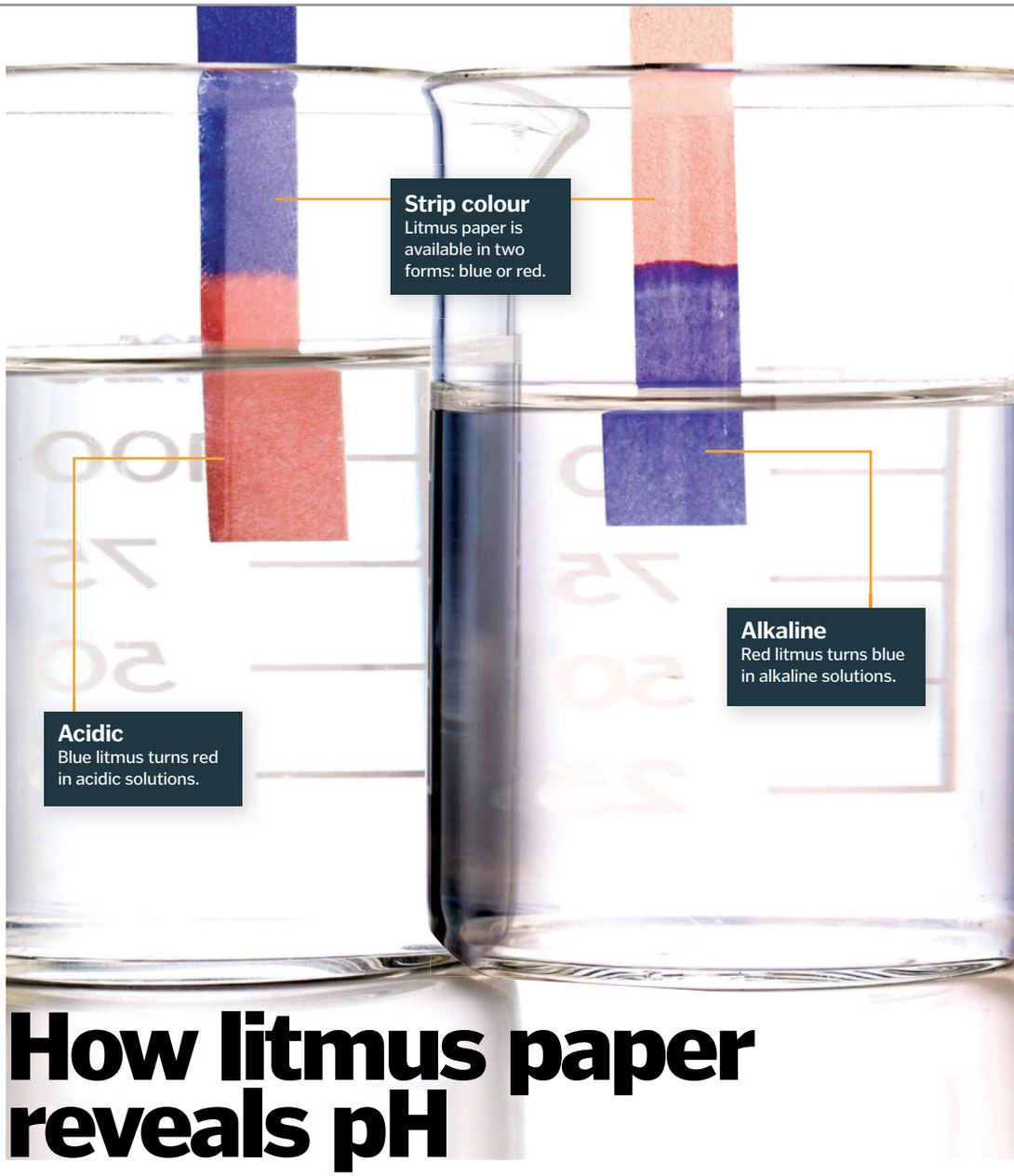
Ventricular systole
The ventricles contract, increasing pressure as the volume of the chambers decreases.



Atrial diastole
The electrical current moves past the atria and the muscles relax.

Thick muscle tissue
The more muscular tissue of the ventricles allows blood to be pumped at a higher pressure than the atria.

Semi-lunar valves open
The pressure in the chambers forces blood through the valves and into the aorta and pulmonary artery.



How litmus paper reveals pH

The science behind the simple tool able to identify a solution's acidity

Most young chemists will be familiar with litmus paper from science lessons, and older chemists for assessing their home brew. This helpful tool is used to determine the acidity or alkalinity of a solution through a simple colour change, where acidic solutions turn the paper red, and alkaline (basic) solutions turn the paper blue. This provides a visual indication of the pH, which is a measure of the concentration of hydrogen ions in a solution.

Water molecules can be broken down into positively charged hydrogen ions and negatively charged hydroxide ions. Acidic solutions have higher concentrations of hydrogen ions than hydroxide ions, while the opposite is true of basic solutions. In water and other neutral solutions, the concentration of hydrogen and hydroxide ions is equal.

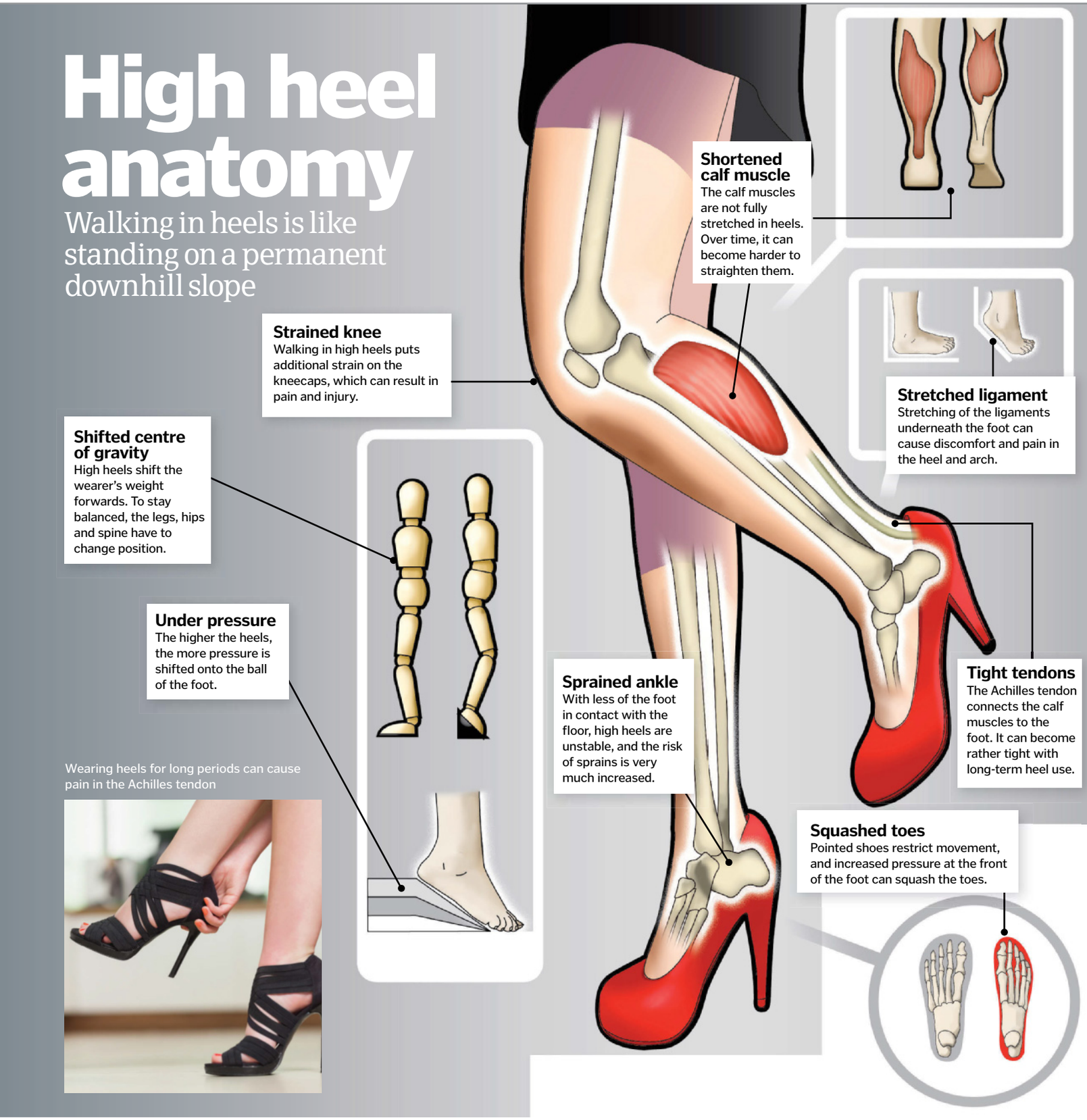
The colour-changing properties of the paper are due to crushed and fermented lichen that has been dried onto the surface. Lichens are a diverse group of organisms, many of which possess large, light-absorbing molecules called chromophores. These absorb differing wavelengths of light depending on their atomic structure, which can be altered by the presence of the ions found in acidic and basic solutions.

Wavelengths at the blue end of the visible spectrum are absorbed when the chromophores react with hydrogen atoms, and wavelengths at the red end of the spectrum are absorbed when the chromophores react with hydroxide ions present in bases.

Depending on which wavelengths of light are absorbed, the paper will appear a different colour. We can then use this colour to determine if the solution is acidic or basic.

High heel anatomy

Walking in heels is like standing on a permanent downhill slope



Shortened calf muscle
The calf muscles are not fully stretched in heels. Over time, it can become harder to straighten them.

Strained knee
Walking in high heels puts additional strain on the kneecaps, which can result in pain and injury.

Stretched ligament
Stretching of the ligaments underneath the foot can cause discomfort and pain in the heel and arch.

Shifted centre of gravity
High heels shift the wearer's weight forwards. To stay balanced, the legs, hips and spine have to change position.

Under pressure
The higher the heels, the more pressure is shifted onto the ball of the foot.

Sprained ankle
With less of the foot in contact with the floor, high heels are unstable, and the risk of sprains is very much increased.

Tight tendons
The Achilles tendon connects the calf muscles to the foot. It can become rather tight with long-term heel use.

Squashed toes
Pointed shoes restrict movement, and increased pressure at the front of the foot can squash the toes.

Wearing heels for long periods can cause pain in the Achilles tendon

High heels force the wearer to walk on tiptoe, bearing most of their weight on the balls of their feet. In this position, the arches are curved, and the ligament that connects the ball of the foot to the heel is stretched. The ankle has greater range of motion in this pose, but it is less stable, and the calf muscles cannot fully stretch out. To remain balanced, the whole body must adjust: the hips tip back, the lower back arches, and the walk cycle changes.

Normal walking gait has two phases: stance and swing. Stance can be further broken down into three parts: contact, as the heel strikes the floor; midstance, as the foot is flat on the floor; and propulsion, as the toes push off again.

During the heel strike, the foot needs to act as a shock absorber, but if it is tilted forwards, it is less able to do this. In midstance, the foot should spread the load, but in high heels most of the foot is off the ground. And when the toes push off the ground, they should flex to provide propulsion, but if they are already bent, they have a much smaller range of motion. The result is shorter, less stable steps.

Heels might be the height of fashion, but wearing them comes at a cost.

COSMIC CATASTROPHES

Discover some of the most dramatic and destructive events in the universe

Flying rocks
Debris from the Moon's explosion would batter Earth and make space travel impossible.

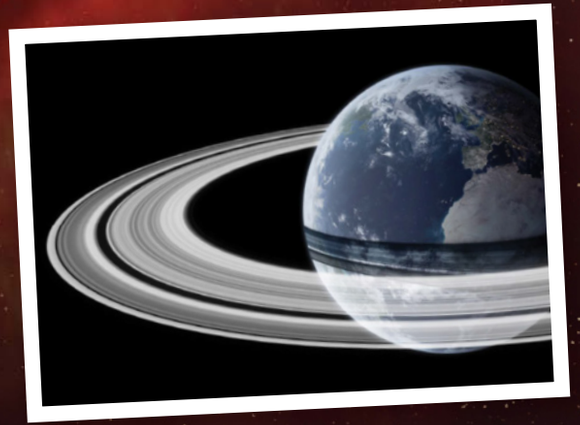
Chaos on Earth
Without the Moon, Earth would start wobbling, oceans would stagnate and seasons would last for years.

WHAT IF THE MOON EXPLODED?

If the Moon were destroyed by some hypothetical event, it's fair to say it probably wouldn't be good news for us – although the method of destruction is important. If the Moon just cracked into several large pieces, they would likely coalesce together again over time. But if it were blown to smithereens, it would create a huge amount of debris.

Over the following few years, some of this debris would rain down on Earth, striking our surface and destroying everything in its path, and heating the oceans until they start to evaporate. The rest, still in orbit around Earth, would settle down over time into a flattened ring shape, not unlike Saturn. But it's likely the remaining debris could make space inaccessible to any humans that are left.

Without the Moon, our planet would be devoid of its tidal effects, ceasing lunar tides and halting the spread of nutrients via the shifting ocean. The result would be a mass extinction.



Humans might go extinct, but we'd have some picturesque rings round our planet

What the asteroid giveth, the asteroid can taketh away

"Asteroids may have played a role in bringing water to Earth"

ASTEROID OBLIVION

Asteroids are the remnants of the protoplanetary disc that gives birth to a star and planets. Unable to merge into larger bodies, they are left to drift endlessly around systems.

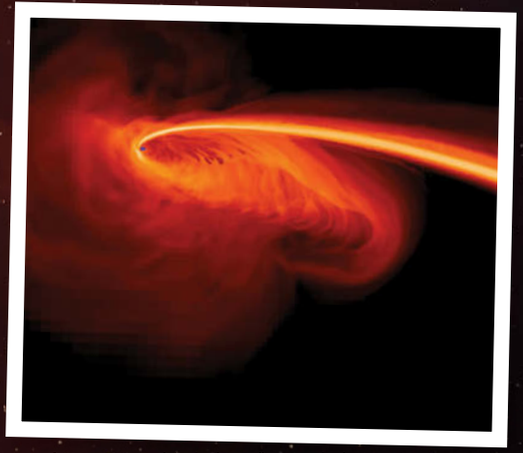
In our own Solar System, this can cause havoc, not least because each planet has a gravitational pull that hurls these hunks of rock and ice towards them. Early in the Solar System from 4.1 to 3.8 billion years ago, during a period known as the Late Heavy Bombardment, the number of asteroids was so great that many of the worlds were pummelled. We can still see evidence of this period on places like the Moon today.

It's not all bad, though. Asteroids are now believed to have played a role in bringing water to places like Earth, and they may even have delivered the building blocks of life too.

HUNGRY BLACK HOLES

Inside the event horizon of a black hole, gravity is so intense that nothing – not even light – can escape. And when a stars wanders too close, the results can be catastrophic.

On several occasions, astronomers have witnessed the results of a black hole eating a star. Stars can get caught in elongated orbits around black holes, and as they pass near, their material is torn off. The star's gas is pulled into an accretion disc around the black hole, and powerful magnetic fields can fire this material back out in a jet that approaches the speed of light.



A computer simulation of a star being swallowed by a black hole

How a black hole eats a star

Come too close to a black hole and your end could be nigh

1 Star
A star on an elliptical orbit sweeps towards a black hole, possibly a supermassive one at the centre of a galaxy.

2 Material
As the star swings close, its outer shells of gas are ripped off by the black hole, and enter its accretion disc.

3 Accretion disc
Around a black hole, this accretion disc can become superheated, known as a quasar. Only a dense remnant of the star's innards remains.

4 Jets
Some of the infalling material is focused into a powerful, narrow beam by the black hole, and is fired back out into the cosmos.

WHEN STARS EXPLODE

Rarely has the phrase 'go out with a bang' been more apt than when referring to the death of a star. These huge explosions can momentarily outshine an entire galaxy, as an immense amount of energy is released in a matter of seconds.

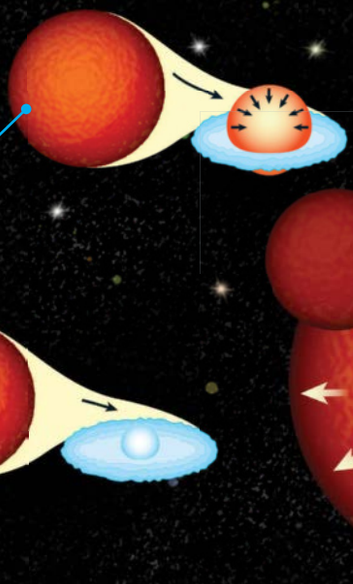
Supernovae can occur in two ways. If two stars orbit closely enough in a binary system, and one of the stars is a white dwarf, this smaller, denser star can siphon off material from its companion. Eventually, it accumulates so much matter that it sets off a runaway nuclear chain reaction, causing the white dwarf to explode in a brilliant flash of light that can be 5 billion times brighter than our own Sun.

Stellar explosions can also occur when a large star dies in what is known as a Type II or 'core collapse' supernova. Giant stars with masses around eight to 15 times that of the Sun eventually run out of hydrogen to fuse. These stars then begin fusing heavier elements like helium and carbon, so the core becomes much denser. This eventually triggers an implosion which rebounds off the core, blasting the star's material out into space as a powerful supernova.

Supernova 1994D, visible here on the lower left, was a Type Ia explosion that occurred on the outskirts of galaxy NGC 4526, 50 million light years away

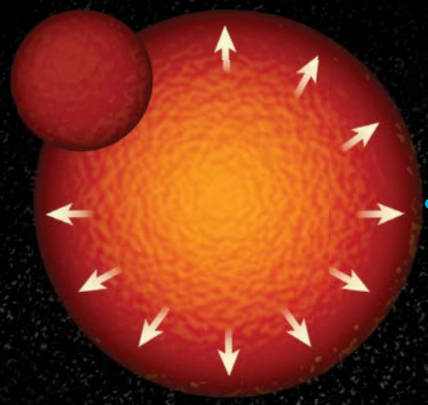
Type Ia supernova

How two stars can combine to produce a massive explosion



Type Ia
A Type Ia supernova occurs in a binary system where a white dwarf orbits another star, usually a giant or another white dwarf.

Transfer
The white dwarf gradually becomes more compressed as it starts to take material from its companion.



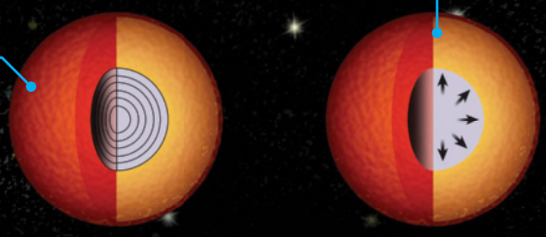
Explosion
Eventually, if the white dwarf reaches more than 1.4 solar masses, it can violently explode as a Type Ia supernova.

"A supernova explosion can momentarily outshine an entire galaxy"

Type II supernova

How a massive star can explode all by itself

Balance
Giant stars are kept stable by the inward force of gravity being countered by the outward pressure of nuclear fusion.



Type II
If a star is eight to 15 times as massive as the Sun, it is able to end its life in a Type II supernova.

Implosion
But when the star runs out of fuel, fusion at the core stops, and the star implodes.

Rebound
Within a fraction of a second, the core collapses, but it then rebounds and produces a shock wave.

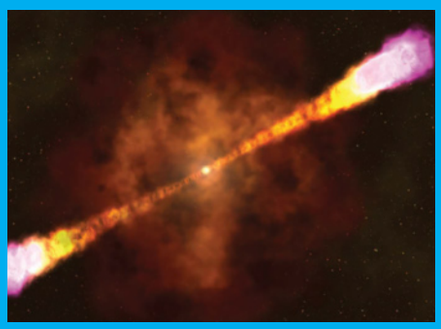
Remnant
After the explosion, all that will be left is an extremely dense, rapidly spinning core. This is known as a neutron star.

Supernova
The shockwave obliterates the star, and blows its outer layers into space.

GAMMA RAY BURSTS

Gamma ray bursts (GRBs) are the most energetic events in the universe. They shine a million trillion times brighter than our Sun, and are thought to be caused either by massive supernovae or the merging of two neutron stars.

When they occur, they release more energy in ten seconds than the Sun will emit in its lifetime, focused along two opposite beams that stretch many light years into the distance. GRBs have been linked to ancient mass extinctions on Earth, with increased levels of carbon-14 isotopes in tree rings possibly linked to these events.



Gamma ray bursts have the potential to end life on Earth

WHAT IF THE SUN DISAPPEARED?

We wouldn't know about it for eight minutes, as that's how long its light takes to reach us. But the temperature on Earth would drop to more than a hundred degrees below freezing in weeks, causing the atmosphere to freeze and fall to the planet's surface. This would leave us exposed to cosmic radiation.

The core of our planet would retain heat, but it's unlikely much life on the surface would survive for long. Life at the depths of the oceans could theoretically survive for billions of years without the Sun. Our world would maintain its momentum and journey the galaxy as a rogue, lifeless planet.

Without the Sun, Earth would be doomed to life as a rogue planet

WILL THE UNIVERSE TEAR ITSELF APART?

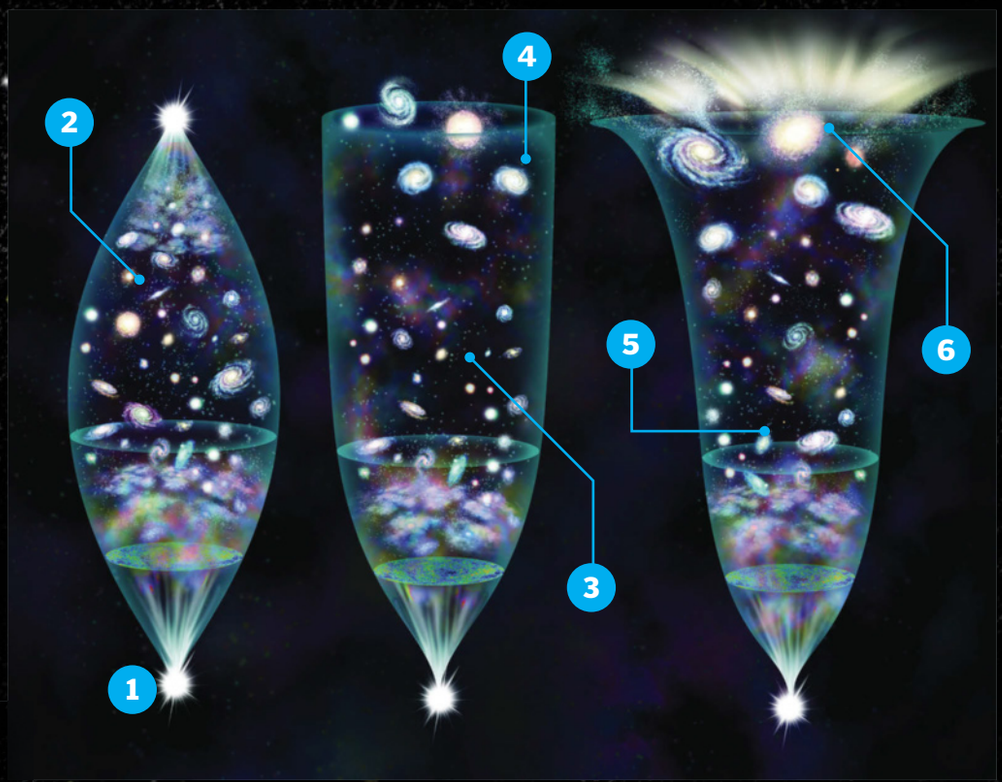
There are three dominant theories for how the universe will end: The Big Crunch, The Big Freeze, and the Big Rip. The former envisions a scenario where gravity causes the universe to contract, until it collapses into a singularity – sort of like an opposite Big Bang. The Big Freeze scenario, the one most favoured at the moment, is where the universe continues expanding but its energy continues to dissipate, to a point in 100 trillion years or so where everything is so spread out that the universe becomes lifeless.

The most dramatic of the three theories, though, is the Big Rip. This is a scenario where the acceleration of the universe continues to get faster and faster, with no limit. Eventually, the force of dark energy would become so strong that it would overcome all the fundamental forces – including gravity and electromagnetism. The result is that galaxies, stars and planets would be literally ripped apart.

Most scientists think the Big Freeze is the likeliest to happen. But, as we don't yet truly understand dark energy, the Big Rip remains a possibility – and some say it could even occur as soon as 50 billion years from now.

In the Big Rip scenario, the universe continues to expand faster until galaxies and even atoms are torn apart

"Galaxies, stars, and planets would be literally ripped apart"



How the universe could end

The main theories for the fate of the cosmos

1 Big Bang
All three scenarios relate to the expansion of the universe after the Big Bang.

2 Big Crunch
This theory suggests the universe will one day collapse in on itself.

3 Expansion
The universe is expanding at an accelerating rate, but we don't know for how long.

4 Big Freeze
In this theory, everything in the universe spreads out to nothingness.

5 Dark energy
No one yet knows the exact role that dark energy will play in our fate.

6 Big Rip
If the expansion of the universe keeps accelerating, everything could be torn apart.

How fast are you moving?

We may feel like we're standing still, but in fact we're flying through space at incredible speeds

Earth's rotation
0.47km/s

The Earth turns on its axis once every 24 hours, which means we're moving nearly half a kilometre every second. We don't feel this motion because the planet and everything on it is constantly moving at the same speed.

Expansion of the universe
73km/s per megaparsec (one megaparsec = 3.26mn light years)

The universe began with the Big Bang, an explosion that threw all of the matter in the universe from a singular point out in every direction. This outward movement is still happening, propelling us ever further from the centre.

The Milky Way's motion
1,000km/s

Our galaxy is one of a cluster known collectively as the Local Group. These galaxies are moving through space towards a gravitational anomaly 150 million light years away, known as the 'Great Attractor'.

Earth's orbit around the Sun
30km/s

The Sun's huge gravitational pull brings us into an orbit from nearly 150 million kilometres away. We move incredibly fast to complete a full circuit in just 365 days.

The Solar System's orbit
230km/s

All stars and planets in the Milky Way orbit the centre of the galaxy. Our Solar System completes an orbit in one 'galactic year', which is 230 million Earth years.

Dark nebulae

The giant interstellar clouds that give birth to stars

Have you ever looked up at the night sky to see a patch of blackness surrounded by a sea of luminous stars? Instead of empty space you may have found a dark nebula, a gargantuan cloud of dust that could swallow our entire Solar System. The specks of dust in the clouds are formed mainly of dirty graphite, ices and carbon-based 'goo'. These components absorb and diffract light, blocking and obscuring our view of the stars that lay beyond.

The Great Rift is a collection of dark nebulae that actually splits our view of the Milky Way. Together, these nebulae weigh 1 million times the mass of our Sun, and span hundreds of light years. And in this region of space, new stars are being born.

Turbulence within the cloud causes 'knots' of matter to form, which have enough mass to start collapsing under their own gravity. As the ball of dust contracts, and its density increases, the temperature rises, and the core starts to rotate. This dense, hot core is a protostar, which will develop into a star over hundreds of thousands of years.

A dark nebula called Lupus 4 obstructs light from distant stars

Space lasers

Find out why artificial stars are lighting up the Chilean sky

The Paranal Observatory's 22-watt laser guide stars are the most powerful ever used in astronomy

When we think of a collection of lasers coming together to point at a distant object, we inevitably picture the destructive force of the Death Star. But while these space lasers may look like sci-fi weapons, they are now a reality, helping us to discover more about our universe.

The 4 Laser Guide Star Facility at the Paranal Observatory in Chile fires four beams – each one about 4,000 times more powerful than a standard laser pointer – toward the sky. The light from the lasers excites sodium atoms in the atmosphere and causes them to glow, creating artificial stars that the observatory can use as a reference point.

The ability to create artificial stars is highly advantageous to an astronomer viewing the galaxy from Earth. Unlike telescopes in space, telescopes on the planet have the atmosphere to contend with, which can blur images (see 'The problem with twinkling stars'). A process called adaptive optics has been developed to correct these distortions, which involves using a relatively bright star near to the target as a reference, allowing crisp images to be obtained that nearly match those taken by space-based telescopes.

Not all targets have a suitable star nearby, but fortunately laser guide stars can be used to generate a reference point to compensate for this. With the help of this futuristic system, the telescopes at Paranal can see the universe more clearly than ever before.

The problem with twinkling stars

Astronomers must be struck with a sense of irony when they look up at the glistening stars in the night sky, as the phenomena that once inspired them as children only hampers their progress as grown-up scientists.

Although stars seem to vary in brightness, their output of light is largely consistent; the twinkling we see is actually due to Earth's atmosphere. Variations in wind speed, temperature and atmospheric density affect the path of light, so it doesn't travel in a straight line. Since stars are so distant, even slight atmospheric changes can be the difference between their light hitting or missing our eyes. This is what makes stars seem to twinkle, and causes the images taken from telescopes to appear blurred.

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Saturn's atmosphere

Uncovering the composition of this ringed mass of gas

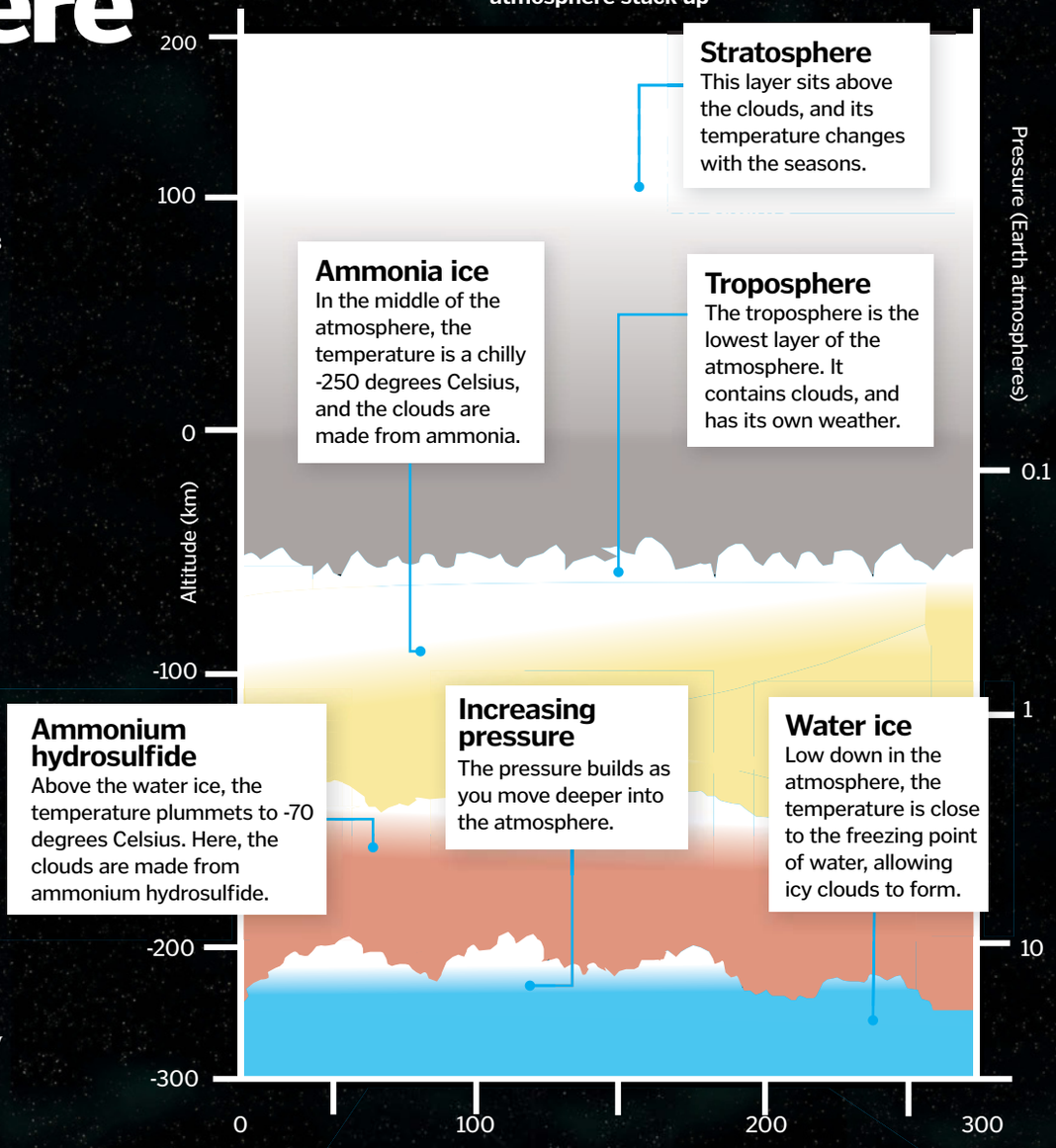
While our own planet is a mixture of oxygen, along with silicon, iron and other solid, rocky elements, Saturn is made almost entirely from hydrogen and helium, both of which are gases on Earth. You might wonder how you are able to tell the difference between planet and atmosphere when dealing with a gas giant, but Saturn isn't gas all the way through.

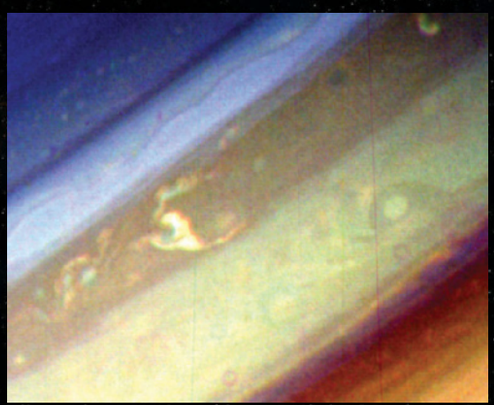
Saturn is 100 times the mass of Earth and ten times as wide, and as you get closer to the centre, immense pressure forces the particles together until they form a liquid. Around the outside, Saturn has a proper atmosphere with wind and weather. In fact, according to the European Space Agency, it is one of the gustiest places in the Solar System, with wind speeds reaching an eye-watering 1,800 kilometres per hour (the record here on Earth is less than a quarter of that speed). It contains layer after layer of gas, and different types of clouds, separated by temperatures that get progressively colder the further away from the planet they go. Sulphur in the atmosphere's clouds gives the planet its orange colour.

Our understanding of Saturn's atmosphere has so far been down to the work of telescopes and spacecraft that peer into the gas from afar. However, NASA's Cassini spacecraft is currently on a trajectory towards the planet itself. The probe will be destroyed on this final mission, but on the way it will gather valuable information about Saturn's gravity and magnetic field, as well as take some close-up photos of the planet and its famous ring system.

Inside Saturn's atmosphere

Take a look at how the layers of Saturn's atmosphere stack up



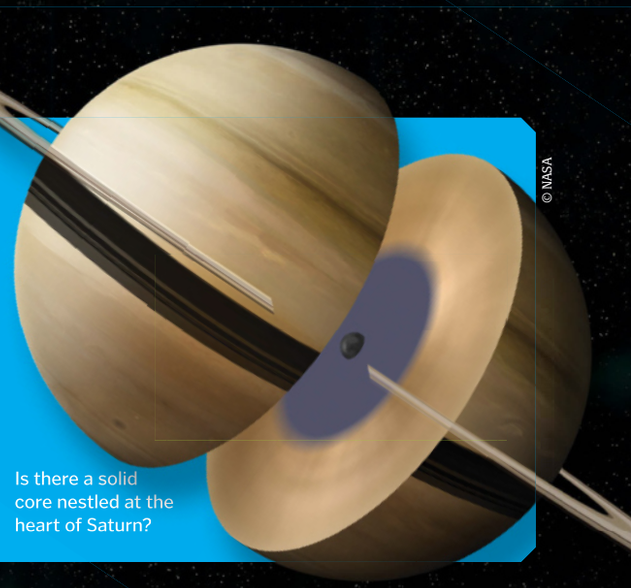


This enhanced colour image of Saturn's clouds was taken by the Voyager 1 probe in 1980

Inside a gas giant

It is likely that Saturn originally formed from a rock or ice core that grabbed extra gas from the early Solar System, but scientists aren't convinced that it's still there. Saturn is the only planet less dense than water, and it's possible that the core is now liquid. The trouble is, we can't see in through all that gas.

However, it turns out you can learn a lot about the inside of a planet from its rings. Movement inside the planet changes its gravitational field, which, in turn, causes the rings to wobble. Much like using Earth's tremors to understand its core, scientists are trying to use Saturn's wobbles to find out what is happening beneath the clouds.



Is there a solid core nestled at the heart of Saturn?

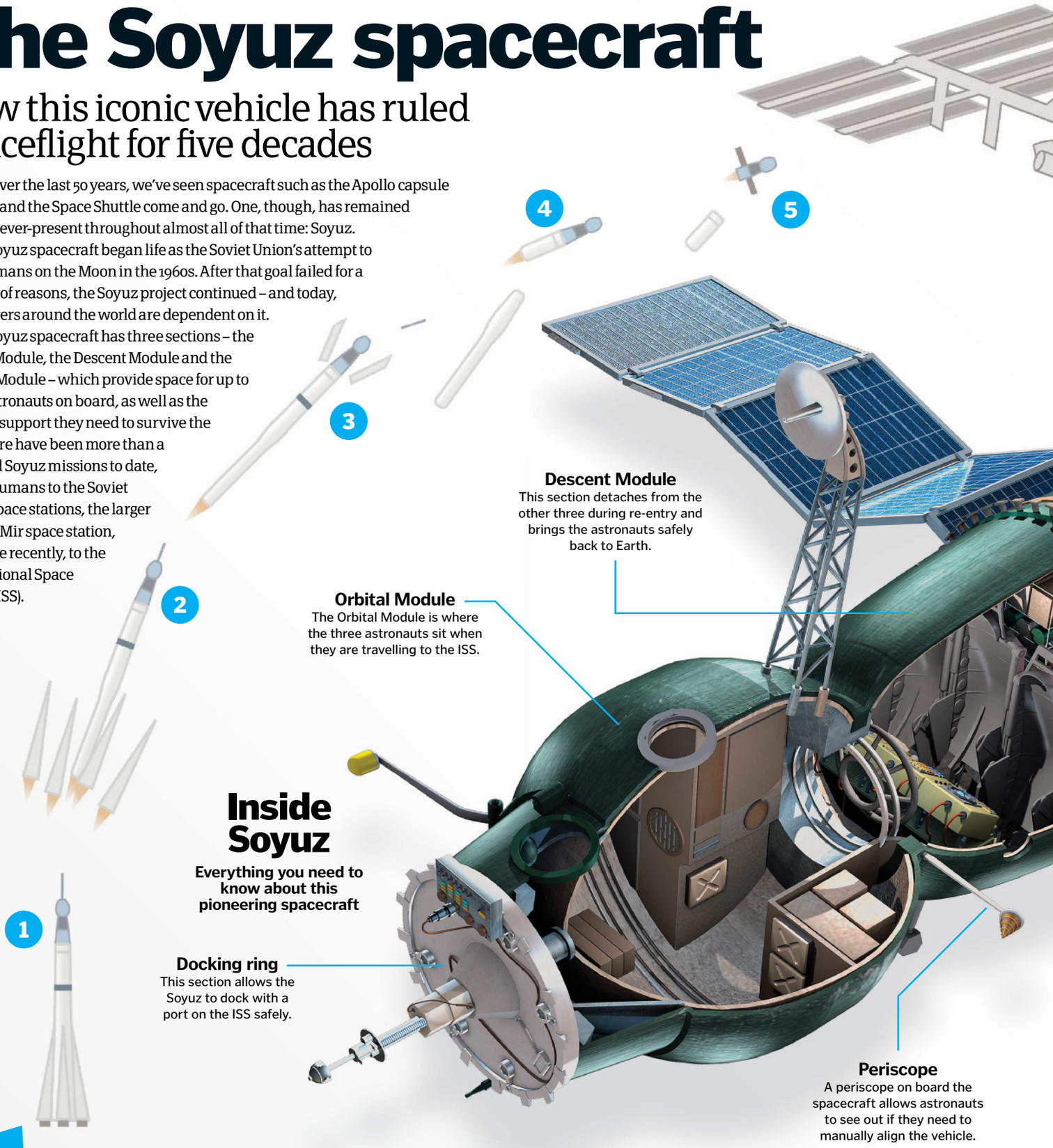
The Soyuz spacecraft

How this iconic vehicle has ruled spaceflight for five decades

Over the last 50 years, we've seen spacecraft such as the Apollo capsule and the Space Shuttle come and go. One, though, has remained ever-present throughout almost all of that time: Soyuz.

The Soyuz spacecraft began life as the Soviet Union's attempt to land humans on the Moon in the 1960s. After that goal failed for a number of reasons, the Soyuz project continued – and today, spacefarers around the world are dependent on it.

The Soyuz spacecraft has three sections – the Orbital Module, the Descent Module and the Service Module – which provide space for up to three astronauts on board, as well as the vital life support they need to survive the trip. There have been more than a hundred Soyuz missions to date, taking humans to the Soviet Salyut space stations, the larger Russian Mir space station, and more recently, to the International Space Station (ISS).



Inside Soyuz

Everything you need to know about this pioneering spacecraft

Launch, docking & landing

How the Soyuz goes to and from the ISS

1. Entry
2 HOURS AND 30 MINUTES TO LAUNCH
The Orbital Module is where the three astronauts sit when they are travelling to the ISS.

2. Pre-launch
5 MINUTES TO LAUNCH
The spacecraft's systems are switched to onboard control.

3. Liftoff
The Soyuz spacecraft launches from the Baikonur Cosmodrome in Kazakhstan.

4. Separation
9 MINUTES AFTER LAUNCH
Soyuz separates from its booster rocket and flies free.

5. Docking
6 HOURS AFTER LAUNCH
Soyuz approaches and docks with the ISS, and the crew enters later.

"There have been more than a hundred Soyuz missions to date"

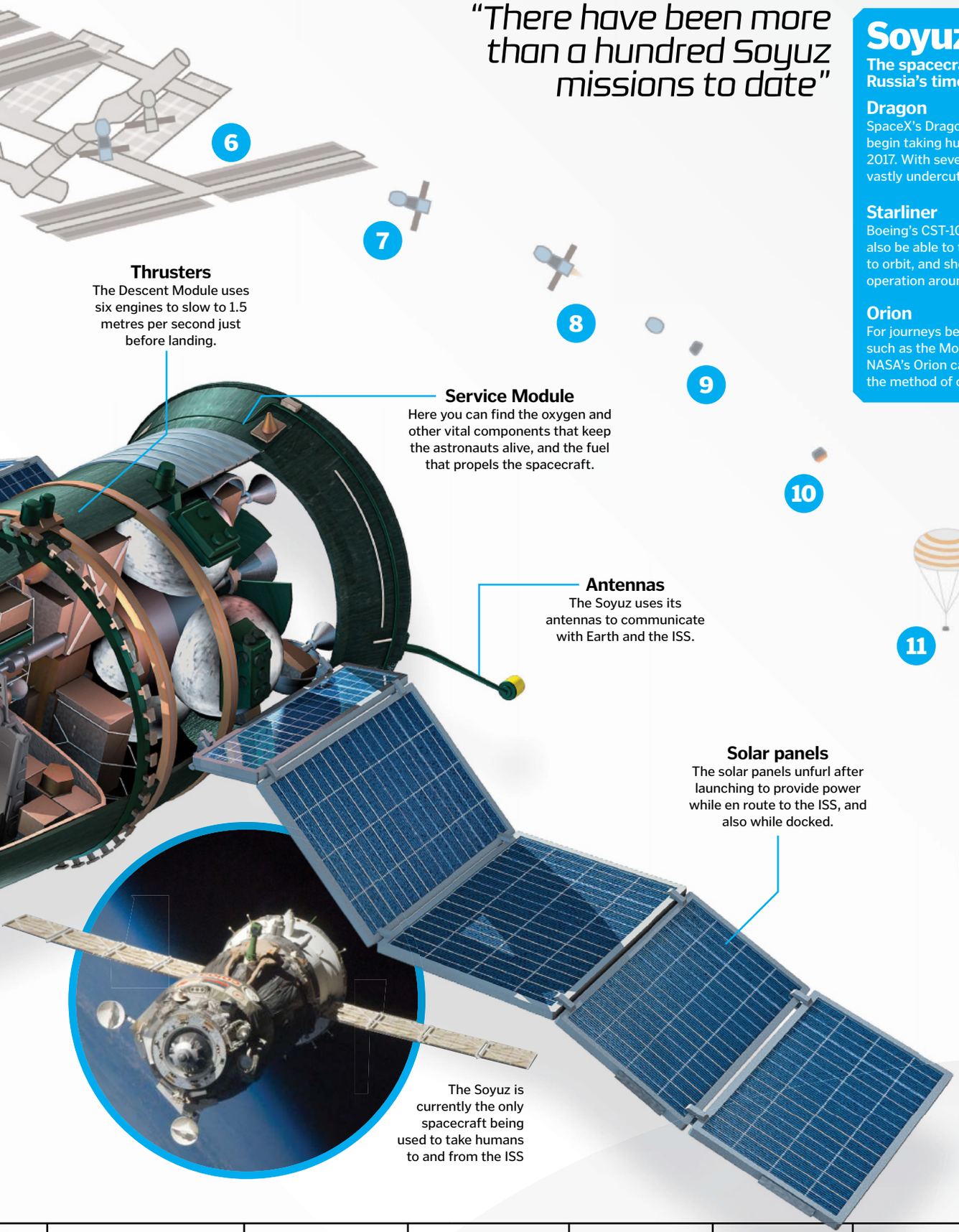
Soyuz rivals

The spacecraft threatening Russia's time at the top

Dragon
SpaceX's Dragon capsule will begin taking humans to space in 2017. With seven seats, it can vastly undercut the Soyuz in price.

Starliner
Boeing's CST-100 Starliner will also be able to take seven people to orbit, and should enter into operation around 2018.

Orion
For journeys beyond Earth orbit, such as the Moon or Mars, NASA's Orion capsule may be the method of choice.



The Soyuz is currently the only spacecraft being used to take humans to and from the ISS

6. Undocking
6 MONTHS AFTER LAUNCH; 3 HOURS AND 23 MINUTES TO LANDING
With the crew on board, Soyuz begins to detach from the ISS.

7. Reverse
3 HOURS AND 17 MINUTES TO LANDING
The Soyuz begins reversing up to 19km from the station.

8. Deorbit burn
54 MINUTES TO LANDING
The Soyuz fires its engines for more than four minutes to prepare for re-entry.

9. Separation
26 MINUTES TO LANDING
The crew, in the Descent Module, separate from the other two modules.

10. Re-entry
23 MINUTES TO LANDING
The Soyuz begins re-entry at an altitude of about 120,000m.

11. Parachutes
15 MINUTES TO LANDING
Two pilot parachutes and a main parachute slow the Soyuz's speed.

12. Landing
Thrusters fire two seconds before landing for a more gentle touchdown.

Every day at 10am, the court would attend the king's mass in the Royal Chapel

The Palace of Versailles

It took 50 years and thousands of workers to build a palace fit for a Sun King

It's a name that conjures images of opulence and grandeur but the history of the Palace of Versailles is by no means golden.

Home to the kings of France for over one hundred years, it started life as a hunting lodge in a village near Paris. Under Louis XIV – the so-called Sun King because the realm orbited around him – it became one of the largest palaces in the world.

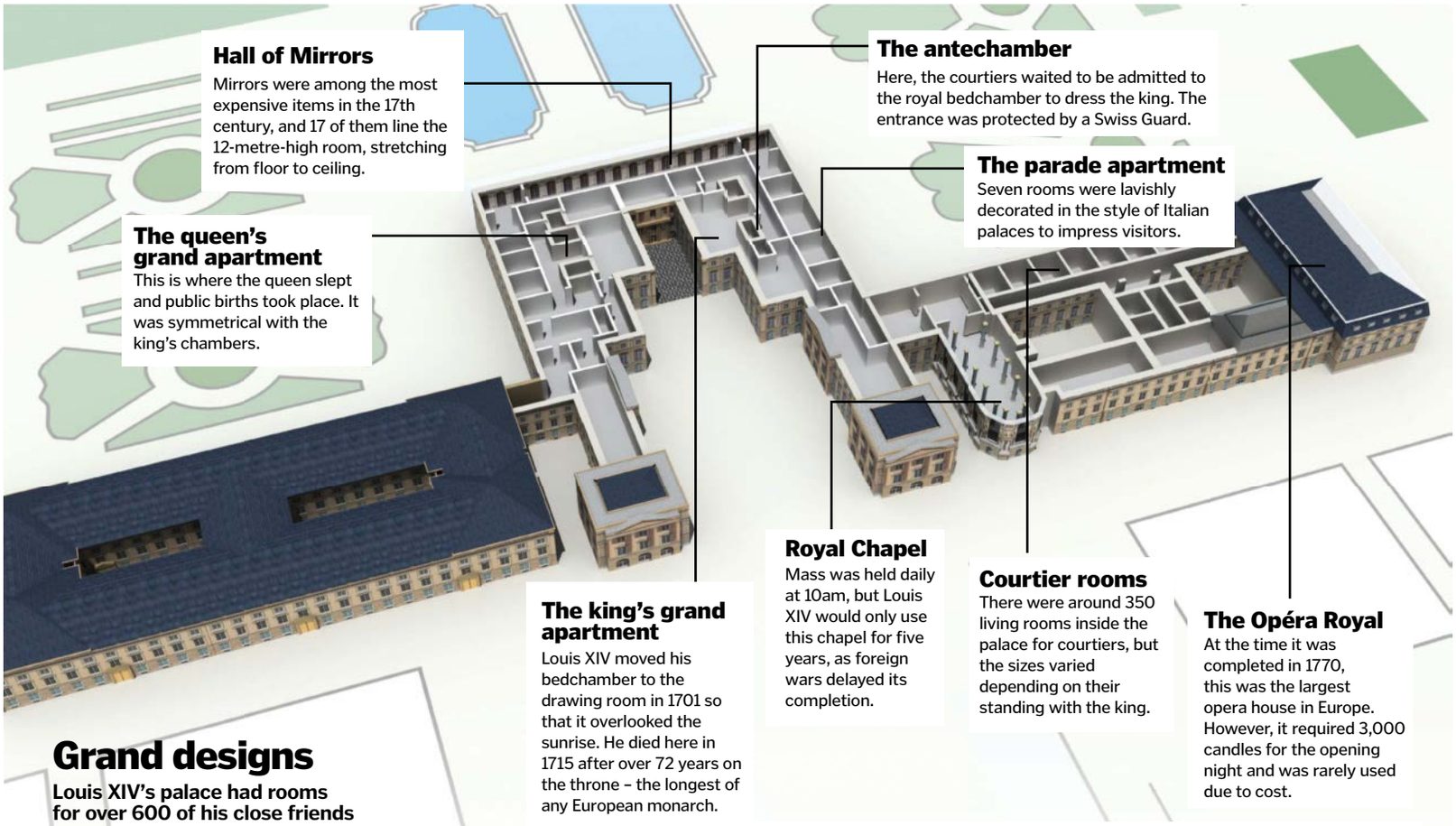
In 1668, he ordered his architect, Louis Le Vau, to build the grand apartments of the king and queen, as well as the stone façade overlooking the garden, known as the Le Vau Envelope. Rather than following the French tradition of slate roofs, Le Vau took inspiration from Italian architecture and created a flat roof hidden by a balustrade.

During the expansion, ministers tried to keep costs to a minimum by using building materials from France – they even nationalised a tapestry factory – but the workmen were the ones who paid the ultimate price.

More than 36,000 men and 6,000 horses laboured from dawn until dusk to construct the 500-metre long building. The workers were paid just six sous per day – the equivalent of a small lump of butter – and the conditions were so poor that three hospitals were built to cope with the number of injuries. Things worsened in the summer of 1668 when debris fell and crushed half a dozen men. What's more, when one of the victim's mothers got close enough to ask the king for her son's body, she was thrown in prison.

Surprisingly enough, Versailles has been likened to a prison itself – a gilded cage that held hundreds of courtiers and nobles captive at the king's pleasure.

It was the setting of magnificent, luxurious parties and many amorous affairs, but what was once the humble hunting lodge would also provide the backdrop to some of history's most momentous events – from the unification of Germany in 1871 to the signing of the Treaty of Versailles in 1919.



Hall of Mirrors
Mirrors were among the most expensive items in the 17th century, and 17 of them line the 12-metre-high room, stretching from floor to ceiling.

The antechamber
Here, the courtiers waited to be admitted to the royal bedchamber to dress the king. The entrance was protected by a Swiss Guard.

The parade apartment
Seven rooms were lavishly decorated in the style of Italian palaces to impress visitors.

The queen's grand apartment
This is where the queen slept and public births took place. It was symmetrical with the king's chambers.

Royal Chapel
Mass was held daily at 10am, but Louis XIV would only use this chapel for five years, as foreign wars delayed its completion.

Courtier rooms
There were around 350 living rooms inside the palace for courtiers, but the sizes varied depending on their standing with the king.

The king's grand apartment
Louis XIV moved his bedchamber to the drawing room in 1701 so that it overlooked the sunrise. He died here in 1715 after over 72 years on the throne – the longest of any European monarch.

The Opéra Royal
At the time it was completed in 1770, this was the largest opera house in Europe. However, it required 3,000 candles for the opening night and was rarely used due to cost.

Grand designs

Louis XIV's palace had rooms for over 600 of his close friends

Learn more

Learn more about the world's most iconic and influential monarchs in the *All About History Book of Kings and Queens*, available now from **www.imagineshop.co.uk** and to download from **www.greatdigitalmags.com**.

The Versailles gardens took 40 years to complete and Louis XIV valued them as much as the palace

©WIKI

A day in the life of the king

Louis XIV's routine was as meticulous and demanding as he was

7:30am : The First Levee begin
A doctor, nurse and a few privileged noblemen file into the king's bedchamber to greet and dress him. They wash and shave him every other day.

10am : Attend mass
As the king walks to the Royal Chapel, a procession lines the Hall of Mirrors. A few attendants try to whisper requests or pass him notes.

11am : The king holds council
In his apartment, the king deals with domestic and religious affairs, as well as matters of the state. Up to six ministers advise him.

1pm : Lunch is served
The king eats lunch in his bedchamber, often with the company of the men of the Court and those privileged enough to be invited to the Levee.

2pm : Afternoon activities
An afternoon of hunting in the surrounding woodland or promenading through the gardens would commence, depending on the king's mood that day.

6pm : Indoor entertainment
Louis XIV's son was often put in charge of the evening entertainment while the king signed the stacks of letters prepared by his secretary.

10pm : The grand public supper
The king and his family eat their meal, observed by as many people as can fit into the antechamber of the king's apartments.

11:30pm : The retiring
After spending time with his family and close friends in his bedroom, another public ceremony is carried out when the king retires to bed.

Fabergé eggs

The fabulous history behind an incredibly lavish tradition

A beautiful example of 19th century Russian art, Fabergé eggs delighted the ruling Romanovs for over three decades. Created by jeweller Peter Carl Fabergé, they were given as gifts between members of the royal family. As time wore on, it became an ever-more extravagant tradition that symbolised royal excesses in the years leading up to the Russian Revolution. Some 50 of these Imperial Easter eggs were created, and each one could take up to a year to create. They were the project of not one, but a whole team of talented craftsmen. One of the most expensive was the diamond snowflake-encrusted 1913 Winter Egg; at a value of 24,600 roubles in 1913 it would cost an eye-watering £2.36 million today. The eggs were designed around a different theme each year, but they all had an immaculately designed exterior with an intricate surprise lying inside. These ranged from mechanical swans to ivory elephants, and some were even powered by clockwork.

As political unrest escalated, Fabergé eggs were seen as a symbol of Romanov wastefulness. After the Bolshevik takeover, many of the eggs were confiscated and the Fabergé family fled Russia. Just 43 Imperial Easter eggs survive today and are owned by collectors, museums and monarchs. The British Royal Family own three of them, including the Mosaic Egg, which is decorated with a mesh of tiny gems, diamonds and pearls, and contains a miniature portrait of Tsar Nicholas II's children.

Fabergé eggs are extremely rare, but many companies produce intricate replicas, such as those pictured here

The first egg

In 1885 Russian Tsar Alexander III needed a present for his wife, Empress Marie Fedorovna. He decided on a jewel-encrusted egg – and began a royal family tradition in the process. Known as the Hen Egg, this first gift appeared relatively simple from the outside, but opened to reveal a golden chicken, which contained a tiny ruby egg pendant and a miniature diamond crown. The Empress was thrilled with her gift and Peter Carl Fabergé was given complete control of all future eggs' designs, with the only prerequisite being that a surprise was hidden within the shell. They continued to be popular gifts under both Alexander and his son Nicholas II.

The Hen Egg was the most basic of the Fabergé eggs on the outside, but contained hidden surprises

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The Siege of Tyre

Find out how Alexander the Great's relentless advance was halted by the determined defence of one city-state

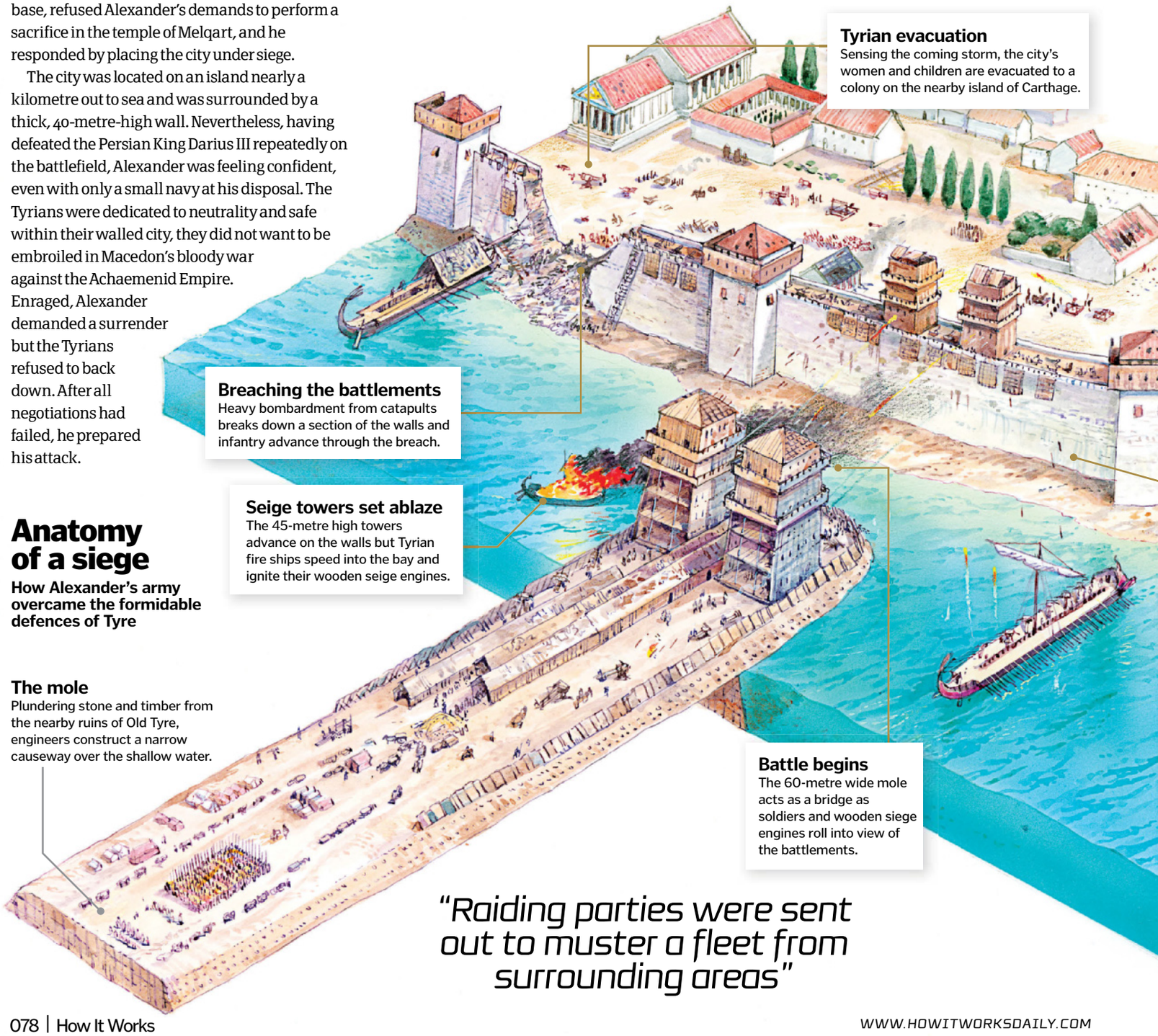
Two years into their conquest of the Persian Empire in 332 BCE, the Macedonian Army faced one of its hardest challenges yet. As Alexander the Great had marched through Phoenicia, many towns, including Byblos, Beirut and Sidon had immediately surrendered. But the walled city of Tyre, an important Persian naval base, refused Alexander's demands to perform a sacrifice in the temple of Melqart, and he responded by placing the city under siege.

The city was located on an island nearly a kilometre out to sea and was surrounded by a thick, 40-metre-high wall. Nevertheless, having defeated the Persian King Darius III repeatedly on the battlefield, Alexander was feeling confident, even with only a small navy at his disposal. The Tyrians were dedicated to neutrality and safe within their walled city, they did not want to be embroiled in Macedon's bloody war against the Achaemenid Empire. Enraged, Alexander demanded a surrender but the Tyrians refused to back down. After all negotiations had failed, he prepared his attack.

The city was clearly impregnable by normal methods of assault, so Alexander looked to alternative strategies for a breakthrough. It was decided that a fleet was required after all and raiding parties were sent out to muster one from surrounding areas. The addition of naval assaults, as well as the construction of a stone causeway, or 'mole', proved to be too much for the city and the walls were finally breached. In the brutal battle that followed, 10,000 residents were executed, while 30,000 more were forcibly sold into slavery. The victory was six months in the making, and proved to be one more example of Alexander's ruthless yet effective military tactics.

Anatomy of a siege

How Alexander's army overcame the formidable defences of Tyre



Tyrian evacuation
Sensing the coming storm, the city's women and children are evacuated to a colony on the nearby island of Carthage.

Breaching the battlements
Heavy bombardment from catapults breaks down a section of the walls and infantry advance through the breach.

Seige towers set ablaze
The 45-metre high towers advance on the walls but Tyrian fire ships speed into the bay and ignite their wooden seige engines.

The mole
Plundering stone and timber from the nearby ruins of Old Tyre, engineers construct a narrow causeway over the shallow water.

Battle begins
The 60-metre wide mole acts as a bridge as soldiers and wooden siege engines roll into view of the battlements.

"Raiding parties were sent out to muster a fleet from surrounding areas"

Alexander the pharaoh

Tyre was the last Persian stronghold in Phoenicia to fall, and the road to Egypt then lay open to Alexander the Great. The young Macedonian had been brought up with tales of the splendour of Ancient Egypt and after witnessing the Great Pyramid with his own eyes, he sailed down the Nile to Memphis.

The Egyptians saw Alexander as their saviour, having liberated them from Persian rule after centuries of repression. Upon his arrival, Alexander was declared Pharaoh and began worshipping Egyptian gods as forms of Zeus. It was during this conquest that he began to seriously see himself as a demi-god as his ego took hold. After founding the city of Alexandria and naming it after himself, he left Egypt in 331 BCE and decisively triumphed over Darius and the Persians at the Battle of Gaugamela. Having been declared 'King of the Four Quarters of the World', Alexander continued his conquests, heading east to take eastern Iran and northern India. He died of malaria in 323 BCE, aged just 32.

Alexandria flourished as a port town, taking Tyre's place as the centre of trade and commerce in the region

Tyre's last stand

The last Tyrian defences congregate in the north of the city but are powerless to stop the bloodthirsty Macedonians.

Victory for Alexander

The King and his family are spared along with those who sought sanctuary in temples. Nevertheless, Tyre now belongs to Alexander.

Harbour blockade

Forced to retreat from the inferno, Alexander changes tack and a flotilla arrives to blockade Tyre's two harbours, surrounding the city.

Heavy resistance

Tyre's defences launch projectiles at the labourers, killing many and slowing the Macedonian approach.

Tyrians refuse to give up

Boulders tossed into the sea prevent the ships from getting to the walls, and burning sand is hurled onto the infantry.

The first colour film

How a little-known Edwardian photographer became the first person to create a colour picture

A still from one of Turner's test films, circa 1902

The first moving colour pictures were created by a London-based photographer named Edward Turner in 1902. Known as the Lee-Turner process (after Turner and his financial backer Frederick Lee), it involved filming consecutive frames of black-and-white 38-millimetre film through three colour filters: blue, green and red. A lens combined each of the three filters' images on the screen to create a single, full-colour projection.

Despite his breakthrough, the timing and positioning of the filters had to be so precise that the results were often blurry. Turner died in 1903, aged just 29, but his work was adapted by George Albert Smith, who used just two filters, red and green, for more reliable results. Smith called his two-colour system Kinemacolor.

Over a century later, Turner's ground-breaking footage has been restored for the first time using digital technology and is now on display at the National Media Museum in Bradford, England.

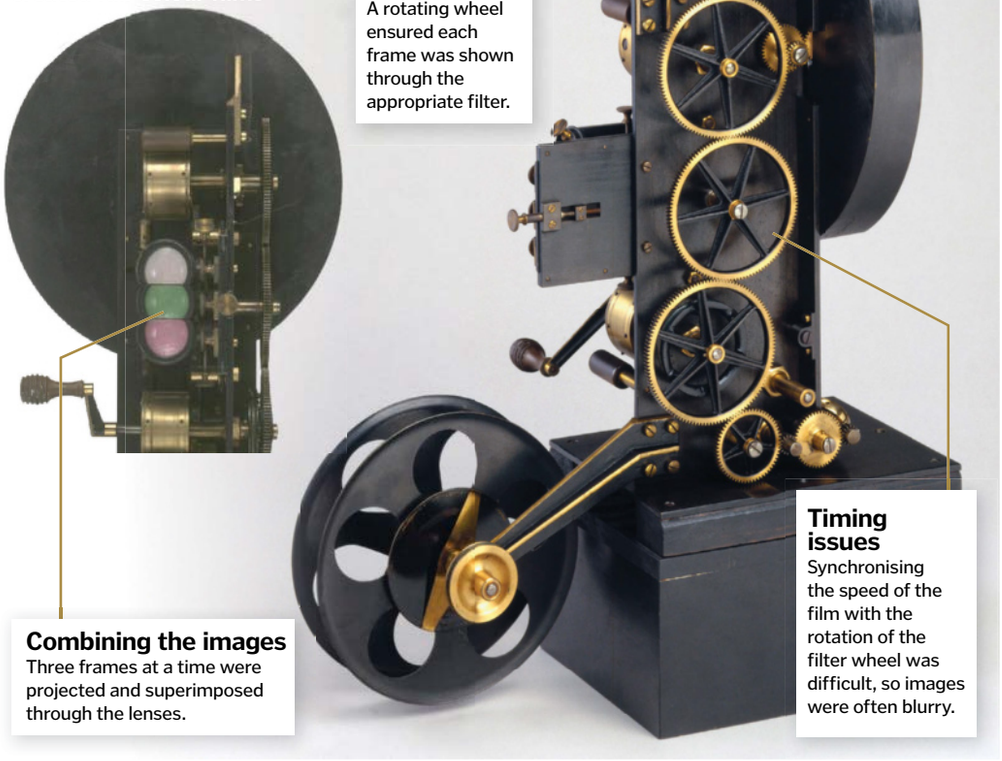
Learn more

To find out more, visit the Lee and Turner exhibition at the National Media Museum in Bradford. Entry is free and it is open Monday to Sunday, 10am to 6pm.

www.nationalmediamuseum.org.uk

The three-colour projector

How the Lee-Turner process created full-colour films



Filter wheel
A rotating wheel ensured each frame was shown through the appropriate filter.

Timing issues
Synchronising the speed of the film with the rotation of the filter wheel was difficult, so images were often blurry.

Combining the images
Three frames at a time were projected and superimposed through the lenses.

The canary girls

Working in Britain's factories during World War One could have serious effects on an employee's health

In 1915, Britain was facing a crippling shell shortage. The crisis was successfully resolved by the passing of the Munitions of War Act, which accepted new, unskilled workers into British factories. Many of the new employees were women and the 'munitionettes' worked day and night filling shells and bullets, operating machinery and building detonators. The workers frequently handled the explosive trinitrotoluene (TNT), which fuelled the cannons on the frontline. Extended contact with the TNT affected the immune system and prevented the liver from ejecting bilirubin from the body. Bilirubin is a brownish yellow substance found in bile that's produced when the liver breaks down old red blood cells. The workers suffered from a build-up of the yellow pigment in the blood, resulting in a toxic jaundice that turned the skin and hair yellow. This is what resulted in the nickname 'canary girls', but the condition was no laughing matter. It brought about further liver problems and could even be fatal, with over 200 women dying from TNT exposure during the war. Despite the hazards, the canary girls had produced 80 per cent of the shells used by the British Army by 1917. Up to a million women worked in Britain's munitions factories but most were dismissed at the end of the war to make way for men returning to work.

The canary girls worked 12-hour days in a noisy, dirty and dangerous environment

Medieval jobs

From catching rats in sewers to juggling for the king, discover the strange careers available in the Middle Ages

The job opportunities open to you in medieval times largely depended on your social class. Those with status were typically nobles, members of the clergy or employed by the royal court, while the peasants, or those without status, worked as craftsmen or labourers. In between were the merchants, who became wealthy by trading the products made by skilled workers all over the world.

All roles were important, as they ensured everyone had the goods and services they needed to go about their lives, but the lower-class workers were often exploited. As a result, the guild system was established. Guilds were organisations that promoted the economic welfare of their members, much like today's trade unions. Most professions had a guild, from merchants and weavers to blacksmiths and candlemakers. Members would set prices and standards for their trade; anyone seeking employment could pay to join and be trained in the represented craft.

Herbalist

Using practical herbal remedies derived from plants and other natural sources, these so-called 'wise women' could treat a wide range of medical conditions. Providing a lifeline for those who could not afford the services of a trained physician, their knowledge of folk medicine was then passed down through the generations.

Squire

Promoted from the position of page boy at 14, a squire was the servant to a knight, and often accompanied him into battle. In return, he would be taught the code of chivalry, the rules of heraldry, bravery, horsemanship, swordsmanship, and other athletic skills, before being promoted to knighthood at the age of 21.

Court jester

Employed by the royal court to entertain the king, a jester would juggle, tell jokes, perform tricks, and generally clown around to improve his master's mood. In return, he was paid well and given a place to live, and enjoyed certain privileges, including being able to make fun of nobles and get away it!

Blacksmith

Every village had its own blacksmith, who would make everything from weapons and tools to door knobs and jewellery. Using charcoal as fuel, they would heat iron until it became malleable, then hammer it into various shapes on a heavy block known as an anvil.

Rat catcher

Rats were a big problem in medieval Europe, spreading diseases and eating crops. Accompanied by a small dog or cat to sniff out the vermin, and various traps and poisons to capture or kill them, rat catchers would walk the streets and sewers, risking contracting the plague to earn a living.

Herald

With so many knights scattered across Europe, each with their own coat of arms, it was the job of a herald to keep track of them all. This also helped them in their other main duty: conducting and announcing the participants of jousting tournaments.

Scribe

As there were no printing presses in medieval times, scribes would copy out text in order to create additional copies of books. This role was often afforded to monks, because they had been taught to read and write, and was hard work, illustrated by the complaints they would often write in the manuscript margins.

Barber

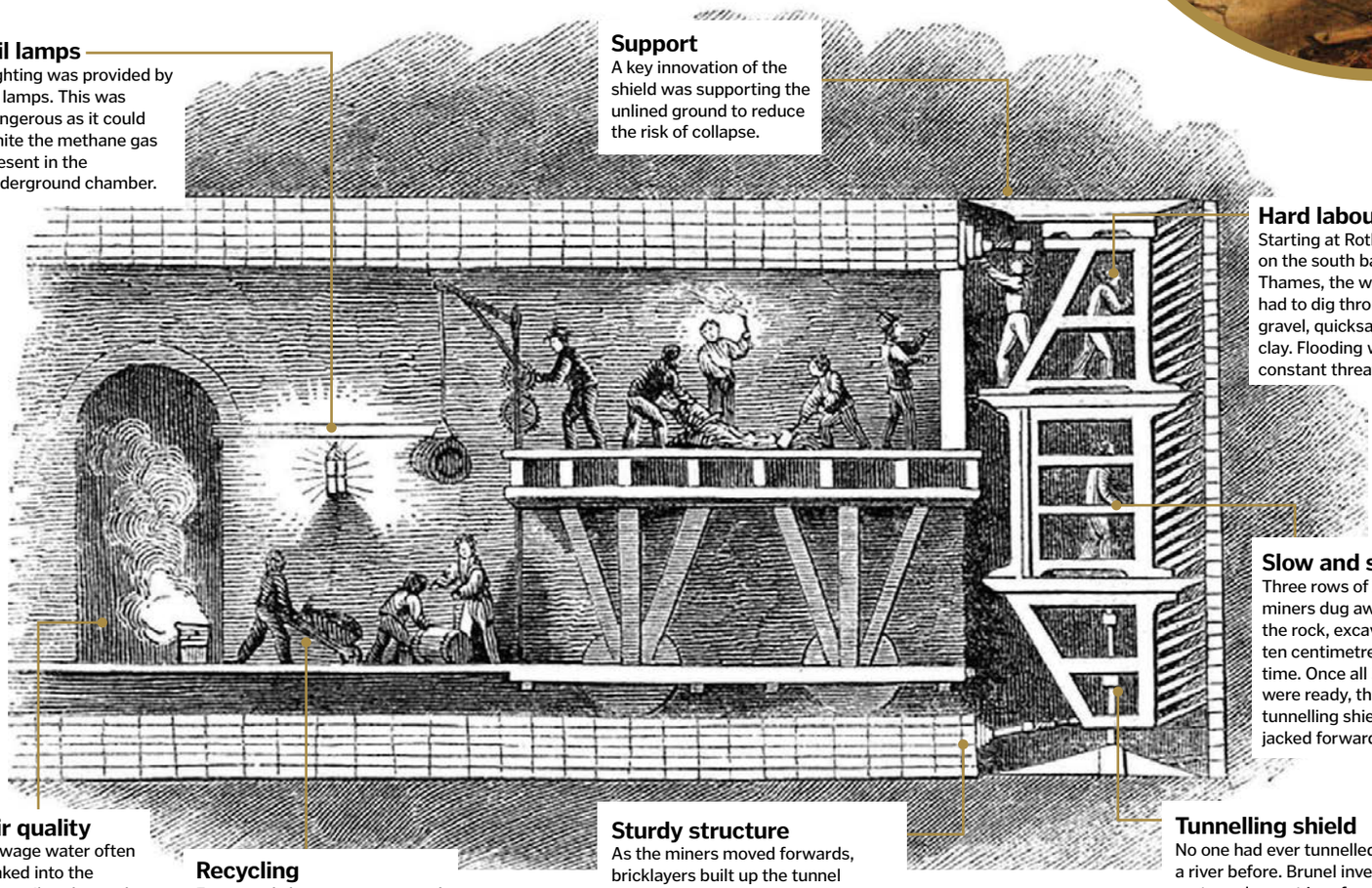
Offering much more than a haircut, medieval barbers would often perform medical procedures too. Known as barber surgeons, they would extract teeth, amputate limbs and carry out bloodletting, the practice of draining the blood to 'cure' various illnesses. With no anaesthetic or training, and only basic tools, it was often a messy affair.

Spinster

In order for wool to be woven, it first had to be turned into yarn. Typically this role was held by women, but male 'spinners' did also exist. They would first twist the fibres between their thumb and forefinger, then attach them to a drop-spindle, the weight of which would stretch the fibres into yarn as they spun.

Building the Thames Tunnel

Finished in 1843, Marc Brunel's sub-aqueous tunnel was the first of its kind



Oil lamps
Lighting was provided by oil lamps. This was dangerous as it could ignite the methane gas present in the underground chamber.

Support
A key innovation of the shield was supporting the unlined ground to reduce the risk of collapse.

Hard labour
Starting at Rotherhithe on the south bank of the Thames, the workers had to dig through sand, gravel, quicksand and clay. Flooding was a constant threat.

Slow and steady
Three rows of 12 miners dug away at the rock, excavating ten centimetres at a time. Once all 36 men were ready, the tunnelling shield was jacked forward.

Air quality
Sewage water often leaked into the unventilated tunnel, making Brunel and his workers ill.

Recycling
Excavated clay was transported above ground, baked into bricks and used to line the tunnel.

Sturdy structure
As the miners moved forwards, bricklayers built up the tunnel behind them. They used a new type of strong, quick-setting cement that made the tunnel watertight.

Tunnelling shield
No one had ever tunnelled under a river before. Brunel invented a rectangular cast iron frame, called a tunnelling shield, to protect the miners as they dug.

A Viking funeral

The distinctive and sometimes brutal customs undertaken during a medieval Nordic funeral

For any Norse warrior who fell on the battlefield, a grand funeral awaited them. Their body was laid in a wooden ship, which was packed full of valuables such as clothes, weapons, jewellery and food. There's even evidence of some chieftains having their servants and horses accompany them into death. Chants and processions were performed at the ritual, and the ship was then buried under a mound or set alight and sent out to sea.

Norse mythology told that the greatest warriors who fell in battle would be allowed to enter Valhalla, a great hall where the mightiest heroes would feast and fight in preparation for Odin's final battle at Ragnarök, the end of the world. The longship symbolised the fastest passage to the afterlife, and it was believed that the higher the flames of the inferno, the quicker the dead would arrive there.

Not every Viking was given a burial this decorative. The poorest in society would be buried in a simple stone boat, while in Sweden in particular, the laying of tumuli (burial stones) was a common practice. These funerals disappeared once Christianity began to spread through Nordic lands.

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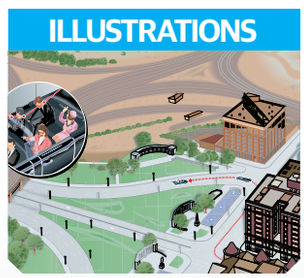

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds that her job comes in very handy for taking part in quizzes!

Joanna Stass

How It Works alumnus Jo is our honorary lake expert after writing a disproportionate number of articles on the subject during her time on the magazine. She has a degree in multimedia journalism and has a keen interest in science and nature.

Along with 31 other species, killer whales are part of Delphinidae, the dolphin family

Is the killer whale a whale or a dolphin?

Morgan Brown

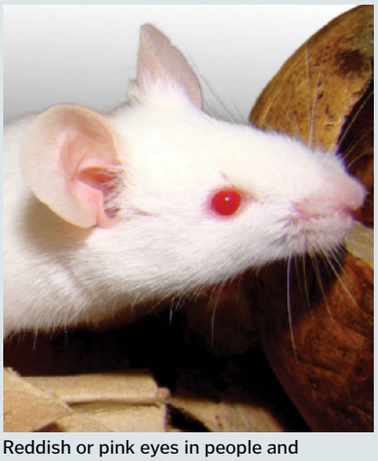
Killer whales, also known as orcas, are the largest members of the dolphin family. Dolphins and whales are however closely related, belonging to the order Cetacea, which also includes porpoises. Sailors named orcas 'whale killers' after seeing them attack whales, and the name was later inverted to 'killer whales'.

Killer whales are found in cold and temperate waters across the world. Many different populations of killer whale exist, exhibiting different morphology, behaviour and diet. Some of these populations have not interbred with other orca populations for hundreds of thousands of years and so could be considered separate species or sub-species. **AC**

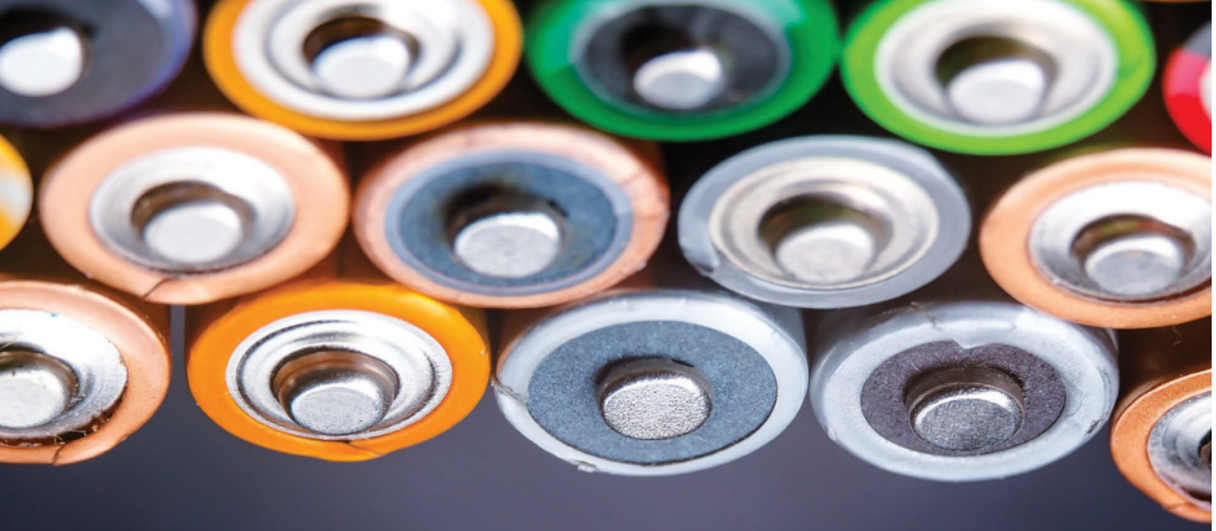
Why can't humans have red eyes and is there any animal that can?

Guy Hodgson

In a way, they can – reddish, anyway. The genetic combinations leading to different colours of eyes aren't fully known and can be complex. Human eye colours include grey, blue, green, brown and black, with various shades in between. The colour depends on the amount of melanin, or pigment, located in the iris. People with dark brown eyes, for example, have lots of melanin, while light blue eyes have less. Some people born with albinism have pink or reddish eyes due to a lack of melanin. This is a genetic mutation that can also be seen in animals such as rabbits and mice, and is accompanied by white fur and pink skin. People with pink or reddish eyes may have light sensitivity, or in more extreme cases, vision problems or blindness. **SF**



Reddish or pink eyes in people and animals is caused by albinism



Why do some AA batteries last longer than others?

The different chemicals inside various AA batteries affect how long they last

Lisa Dang

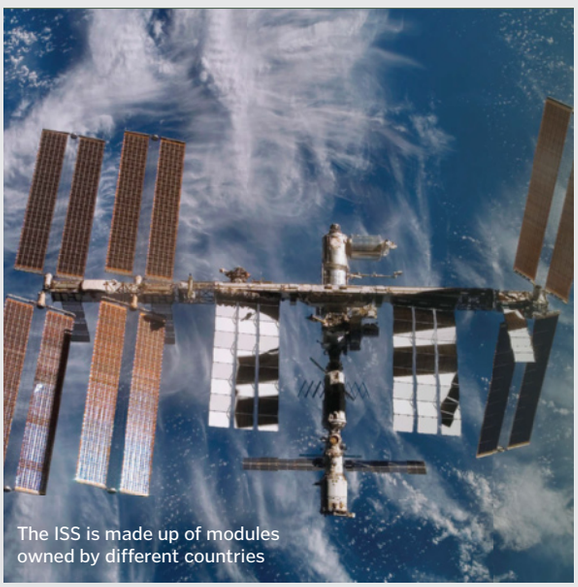
Battery life is affected by various factors. Batteries in warm places lose charge faster than ones kept cool, and the varying quality of materials means cheaper ones often fail before more expensive types. Although AA batteries look alike, the chemicals inside them can be different, with great effects on lifespan. Batteries produce electricity by chemical reactions between two electrodes made of different materials, such as zinc and manganese oxide, and another component called an electrolyte. With use the electrodes corrode and wear out, and the battery dies, but this corrosion happens far faster in batteries that use an acid electrolyte than those with an alkaline electrolyte. **TL**

The main difference between ships and boats is their size

What is the difference between a boat and a ship?

Chris Morden

Ships are normally larger, more complicated and more powerful than boats, making them better suited to sailing the oceans. However, submarines are referred to as boats no matter what their size. **TL**



The ISS is made up of modules owned by different countries

Who owns the International Space Station?

David Brunswick

Just like the science and engineering that make it work, ownership of the International Space Station (ISS) is complicated. Ownership is shared between the different partner organisations, namely the US, Russia, Canada, Japan and the European Space Agency. However, rather than owning a percentage of the whole ISS, different partners each own different parts of it. One side of the station is entirely owned by Russia, while the other side is controlled by the United States, but includes modules belonging to the European Space Agency and Japan. Agreements allow partners to use sections of the space station that don't belong to them. **TL**

BRAIN DUMP

The operating costs of the SR-71 Blackbird spy plane were estimated at $200,000 (£150,000) an hour

Why was the Blackbird SR-71 discontinued?

Sam Griffiths

Designed in the 1960s to spy on the Soviet Union, the American SR-71 Blackbird reconnaissance plane could fly over three times the speed of sound, at altitudes of over 25,000 metres. Even today it would still fly faster and higher than most 21st century airplanes. So why was it retired in the 1990s? After the end of the Cold War and the breakup of the Soviet Union, the Blackbird's original job was no longer relevant. At the same time, new technologies, such as advanced spy satellites and drones, provided new ways to spy on enemies. However, the major reason was cost. The Blackbird was in service for over 30 years, and just as old cars get expensive to run, so too do old aeroplanes as parts need replacing and systems need updating. As military budgets were cut after the Cold War ended, this remarkable old aircraft was just too expensive for the future. **TL**

The benefits of an ice bath may mostly be down to the placebo effect

Why do athletes use ice baths?

John Macintyre

Ice baths or cold rooms cause athletes' blood vessels to contract, reducing blood flow and alleviating the inflammation caused by muscle damage. The ice bath treatment involves sitting waist deep in a bath at around ten degrees Celsius. Although many sportspeople swear by this popular recovery aid, the science behind it is inconclusive. An ice bath may reduce soreness and swelling, but cannot reverse the injury itself. A review of 17 studies concluded that while cold water immersion did reduce muscle soreness by about 20 per cent, it was no more effective than other remedies such as stretching or taking ibuprofen. **AC**

FASCINATING FACTS

Why are truffles so expensive?

Truffles owe their sky-high prices to their rarity and the effort required in collecting them. They cannot be farmed and instead are tracked down using pigs or specially trained dogs. **AC**

European white truffles are the most expensive food in the world

Why do doughnuts have holes?

It is widely believed that the doughnut hole was invented by Captain Hanson Gregory in 1847. He disliked the doughy centre of his fried cakes and so added a hole to ensure they cooked more evenly. **JS**

Others believe that the hole was added so bakers could display doughnuts on poles alongside bagels

Why is air conditioning bad for your skin?

Air conditioning removes moisture from the air, creating an environment with very low humidity. This causes moisture to evaporate from your skin cells, leaving you with dry skin. **LM**

Air conditioners reduce humidity to make a room more comfortable

How do plants protect themselves from sunburn?

Plants over-exposed to UV-B have stunted growth and are susceptible to disease

Francis Barrett

Plants produce their own chemical sunscreens, known as flavonoids, which shield them from the harmful effects of UV-B radiation. Exposure to UV-B light stimulates a doughnut-shaped photoreceptor protein called UVR8, which in turn activates genes that produce flavonoids. This 'sun block' is then deposited on the outer tissues of leaves, where it absorbs UV-B rays, preventing them from entering deeper into the leaf. Exposure to UV-B light also stimulates the production of enzymes that repair damage to DNA, to minimise any harmful effects of the UV-B rays. **AC**

How many galaxies have we discovered?

Lizzie Harfield

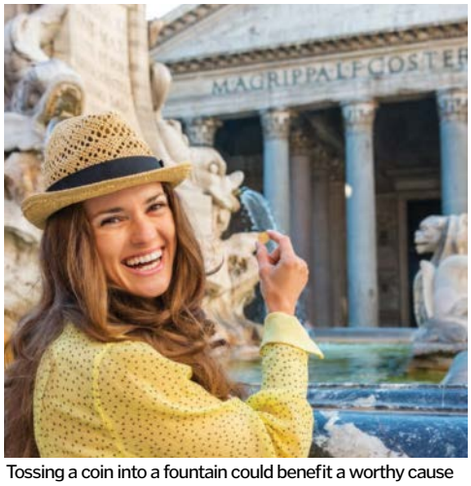
It's believed there are hundreds of billions of galaxies in the observable universe, but the exact number isn't known. To count them all, astronomers need to be able to look deep enough into space, and far enough back in time, to see when galaxies were formed. Using current telescopes, they can see galaxies just over 13 billion light years away, but the universe is 13.8 billion years old, so there is still some way to go. Plus, each telescope can only see a small area of sky at a time, so astronomers can only use their images to make an estimate of how many galaxies are in the entire universe. **JS**

Even by focussing on a tiny patch of apparently empty space, the Hubble telescope can detect thousands of galaxies

What happens to coins thrown into fountains?

Alison Fry

Whether it brings you luck, grants your wishes or simply costs you a penny, throwing coins into fountains certainly benefits someone. Eventually all that loose change is collected by the fountain's owner, who may pocket it themselves, put it towards the upkeep of the fountain, or donate it to charity. Up to £3,000 of loose change collected each day from Rome's famous Trevi fountain goes towards running a supermarket for the city's poor, while the Mall of America in Minnesota lets non-profit organisations apply for a cut of the £18,000 a year thrown into its various water features. **JS**



Tossing a coin into a fountain could benefit a worthy cause

Many languages, such as ancient Egyptian, slowly died out as others started to dominate

Why do languages die?

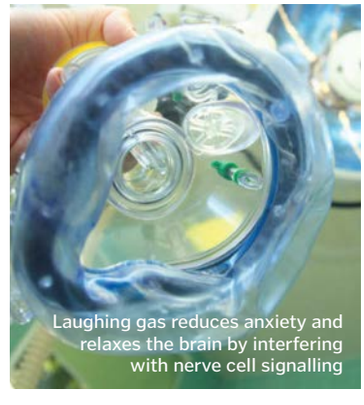
Michelle Wilson

There were once an estimated 20,000 different languages spoken throughout the world, but now there are less than 7,000. The most common way a language becomes extinct is when one language spoken by a bilingual nation becomes more socially dominant than the other. If someone is more likely to find a job or make friends speaking a particular language, then they are likely to favour that one and drop any others they can speak. Alternatively, the two languages may gradually merge into one, as the minority language borrows more and more words and grammar from the dominant one until they become inseparable. **JS**

Why does laughing gas make you laugh?

Sammy Sinclair

Laughing gas, or nitrous oxide, is used for pain relief. It is a small molecule, and when it gets into your bloodstream it travels to the brain and interferes with the transmission of chemical signals from one nerve cell to the next. It has three main effects – pain relief, relaxation, and anaesthesia – and it's the relaxation component that makes you laugh. It has been called 'laughing gas' for over 200 years, and it was originally used recreationally because of the pleasant effects it can have on the brain. However, it can have dangerous side-effects if used without medical supervision. **LM**



Laughing gas reduces anxiety and relaxes the brain by interfering with nerve cell signalling

BRAIN DUMP

All tea leaves come from Camellia sinensis, a plant native to India and China

What's the difference between black, green and white tea?

Madeleine Wheeler

Black, green, and white teas are all made from leaves of the same species of plant, but their differences arise from the level of oxidation that they have undergone during processing. Once tea leaves are picked, they begin to wither. Exposure to oxygen triggers a series of chemical reactions that cause the leaves to turn brown, but it also triggers the production of chemical compounds that change its flavour. White tea is produced from the youngest tea leaves, which are allowed to dry naturally, resulting in a low level of oxidation. At the other end of the spectrum, black tea undergoes more extensive processing. First leaves are left to wilt in sunlight. Then they are crushed, creating cell damage that helps oxidation to occur, and exposed to warm, humid conditions. Finally, heating in an oven terminates the oxidation process. A higher degree of oxidation increases the production of compounds called xanthines, including caffeine, and gives black tea its dark colour. **AC**

You can always tell identical twins apart by their fingerprints

Why do identical twins have different fingerprints?

Isobel Thornton

Identical twins don't have identical fingerprints because of how fingerprints form. The whorls and ridges form during compressions of the skin on a foetus's fingers, in a similar way to land masses buckling to form ridges under compression. Not everything is alike about identical foetuses in the womb; their positions, the lengths of their umbilical cords, their movements, and their exposure to chance fluctuations in hormones will be different. These factors can all affect how the fingerprints of identical twins are formed, so although they may have similarities, they will always be slightly different. **SF**

There is no scientific evidence that dock leaves contain sting-soothing chemicals

Do dock leaves really soothe nettle stings?

Carrie Rutherford

When you brush against a stinging nettle, tiny hairs on the leaf pierce your skin, injecting you with various chemicals that cause a painful stinging sensation. When this occurs, many people will instantly begin hunting for a nearby dock leaf, claiming that rubbing it on the affected area soothes the pain. However, no one quite knows why it seems to help. Some claim it is because dock leaf sap is alkaline, so it can neutralise the formic acid found in nettle hairs, but the sap is in fact acidic too. Others claim that dock leaves contain a natural antihistamine that works against the pain-inducing histamine of stinging nettles, but there is no scientific evidence that this is the case. Therefore, the common consensus is that the leaves merely have a placebo effect, reducing the pain because you believe they have soothing properties. **JS**

How can a person have a 'net worth'?

A person's net worth is all the value of their assets minus their debts

Ciara Elsen

You might think that only the rich and famous have a net worth, but everybody has one. Put simply your net worth is the value of your assets, minus any debts that you might have – it's a measure of your financial wealth. Assets are the value of all your money and any property, shares, investments, cars, antiques and other things of value that you own. Debts are everything that you owe, such as loans and bills. Deduct debts from assets and you've got your net worth – but it probably says more about the things that you have than the sort of person you are. **TL**

FASCINATING FACTS

Why does mouthwash feel hot?

Tom Riley

The alcohol in many mouthwashes can leave your mouth feeling fiery. Some mouthwashes also contain 'hot' ingredients like camphor, eucalyptus, cinnamon, or peppermint to help freshen your breath. **SF**

A cat's extra toes are cute, but they aren't leading to opposable thumbs

It is true that cats are evolving thumbs?

Peter Slymm

Cats usually have five toes on their front paws and four on the back paws. However, some are born with up to eight toes on one or more of their feet. This genetic mutation, called polydactyly, is common in cats. Although these extra toes can allow felines to get a better grip with their front paws, the toes aren't opposable like thumbs are, so there's no evidence that polydactyly means cats are evolving thumbs. The Guinness World Record holder for most toes on a cat is seven toes on each foot for a total of 28, held by Jake of Ontario, Canada. No word as to whether he can open his own cans of food, though. **SF**

How does plastic get broken down by sunlight?

Nick Richards

We know that ultraviolet light from the Sun can be harmful to our skin, but it can also damage plastics. UV light is made up of high energy photons, and when they slam into molecules they can break the bonds that hold them together. This process is known as UV degradation. Plastics are made from long chains called polymers and, when UV light hits, these can start to break apart. The chains are chopped into shorter fragments, and this has disastrous effects on the structure of the plastic, causing it to become weakened, brittle and discoloured. Different types of plastic are damaged by sunlight in different ways. PVC, as found on window frames, can become chalky as the top layer of plastic breaks down to reveal particles that were once trapped inside its structure. Polystyrene, on the other hand, goes yellow, and gradually loses its elasticity. **LM**

Sunlight damages plastics, but they still take centuries to degrade completely

How many species have been made extinct because of humans?

Josh Walker

It's impossible to give a definitive numerical answer, but it's likely to be far higher than the impact of any other species. No other animal changes its environment as much as we do, and our activities have knock-on effects that impact thousands upon thousands of other species. According to a paper published in 2014, extinction rates are 1,000 times higher than they would be if we weren't around.

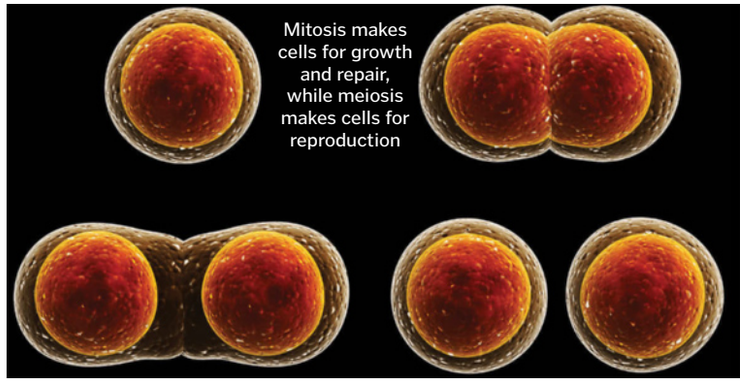
Take a look at the UK, for example. Thousands of years ago, the land was covered in thick forest, and bears, wolves, lynxes and even woolly mammoths roamed the land. We stripped out the trees, hunted the animals, and turned natural landscapes into farms and concrete jungles. **LM**

Thanks to us, badgers and red foxes are the largest carnivores left in the UK

What's the difference between mitosis and meiosis?

Christian Armstrong

Both mitosis and meiosis are types of cell division. Most of the cells in your body have two full sets of chromosomes: one from your mum and one from your dad. When these cells divide for growth and repair, the parent cell makes a full copy of its genetic code before splitting in two, giving two full sets of chromosomes to each daughter cell. This type of cell division is called mitosis. However, there are two types of cell that only need one full set of chromosomes: sperm and eggs. When these cells are being made, the parent cell splits into four, and each gets just one set of chromosomes. This is meiosis. **LM**



Mitosis makes cells for growth and repair, while meiosis makes cells for reproduction

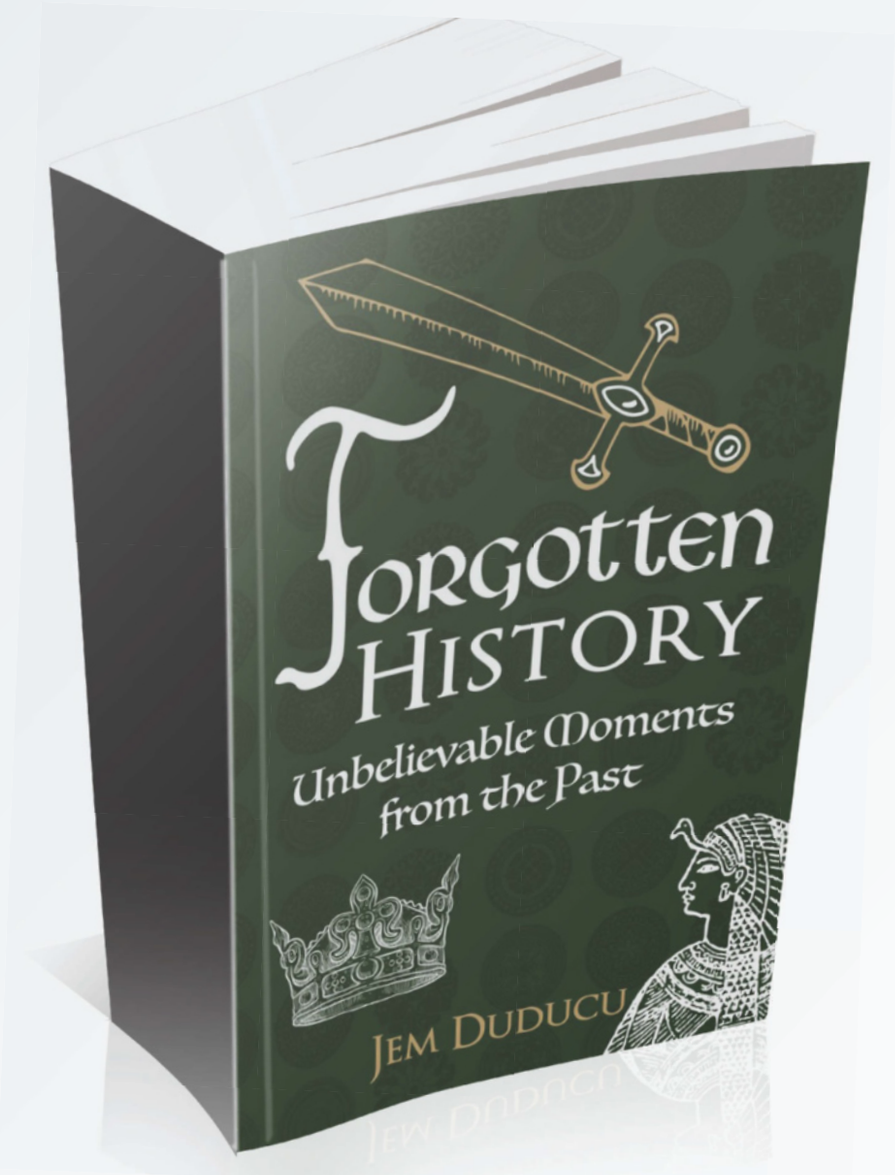
BOOK REVIEWS

The latest releases for curious minds

Forgotten History

Wonderfully weird but true tales you weren't taught in school

- Author: **Jem Duducu**
- Publisher: **Amberley**
- Price: **£20 (approx. $35)**
- Release date: **Out now**



Here at **How It Works**, we are firm believers in history being an exciting subject to explore, rather than just a dull list of dates and names. From menacing monarchs and bloody battles, to extraordinary minds and crazy inventions, the past is littered with remarkable stories worthy of the big screen. However, there are also quite a few little-known tales that are just as fascinating, yet have been left out of the blockbuster scripts. Forgotten History is a collection of these funny, fascinating and sometimes flabbergasting stories that you won't have discovered at the movies, or indeed in your school textbooks.

The idea of the book stems from author Jem Duducu's successful social media account (@HistoryGems), from which he regularly posts fun history facts. Realising the demand for these short snippets of forgotten information – his Facebook page now has over 40,000 likes – Jem decided to compile them into a book, allowing him to go into a bit more detail about some of his favourite anecdotes from the past. Great for those with a short attention span, each story lasts between a few paragraphs and a few pages, making it easy to dip in and out of the book, but beware, you're more likely to find yourself unable to put it down. In-depth research and compelling storytelling make each tale just as fascinating and entertaining as the last, and we defy you to resist reading on when the next sub-heading reads 'The story of the Nazi super cows' or 'Was Jesus's younger brother Chinese?'

The book covers tales from ancient history right through to the 20th century, with myths busted – did you know that croissants aren't actually French? – and new characters introduced – you're guaranteed to be impressed by Sergeant Stubby, the most decorated dog in World War One. After reading just a few pages, you will have a bank of stories certain to impress your friends, from the hilarious tale of the statue put on trial for murder, to the evidence of real-life Hobbits standing at just one metre tall. It's baffling to think that all of these stories are true!

★★★★★

YOU MAY ALSO LIKE...

The Romans In 100 Facts

Author: **Jem Duducu**
Publisher: **Amberley**
Price: **£7.99 / $13**
Release date: **Out now**

Jem has also written a series of *100 Facts* titles condensing different eras of history into fun bite-sized chunks. In this book, he tells the story of one of history's most fascinating civilisations.

The Beastly Best Bits

Author: **Terry Deary**
Publisher: **Scholastic**
Price: **£9.99 (approx. $13)**
Release date: **Out now**

This fantastic compilation takes the best bits from the well-loved *Horrible Histories* books to give you a gory guided tour of the history of the world. Discover the most gruesome deaths from the Stone Age right up to WWII.

The Greatest Stories Never Told

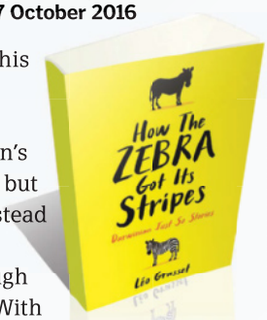
Author: **Rick Beyer**
Publisher: **Harper Collins**
Price: **£14 / $18.99**
Release date: **Out now**

Accompanied by photographs, drawing and maps, this book brings to life 100 astonishing tales that changed the course of history, which you've probably never heard before.

How The Zebra Got Its Stripes

Just So stories with a Darwinian twist

- Author: **Léo Grasset**
- Publisher: **Profile Books**
- Price: **£9.99 (approx. $13)**
- Release date: **27 October 2016**



Questions like this have been the subject of light-hearted children's books for years, but here Grasset instead looks at these questions through Darwin's eyes. With evolutionary theory and his own observations at the forefront, Grasset covers a number of animal peculiarities, such as the air conditioning of termite mounds, or the navigational abilities of the dung beetle.

The book flits from subject to subject a little too quickly at times, but usually does a good job of explaining a subject and casting a scientific eye on the question. For the most part, the answers are just theoretical, which is a little unsatisfying, but this is still a unique and interesting take on evolutionary theory.

★★★★☆

Geek's Guide to Britain

A day-trippers guide to science and tech in the UK

- Author: **Gavin Clarke**
- Publisher: **The Register**
- Price: **£19.99 (approx. $26)**
- Release date: **Out now**

Which country is credited with designing more than half the world's most important inventions? You might think it is Japan, or the US, but in fact it is the UK. To celebrate this, Gavin Clarke put together the Geek's Guide to Britain, in which writers explain the importance of different sites around the UK. From GCHQ in Gloucester to London's Brunel Museum, the book covers a range of locations that are either good for a visit, or just interesting to hear more about. It's not the most gripping book, but it does go to show just how much technological history Britain has.

★★★☆☆

Pirate Radio: An Illustrated History

An in-depth look at the rebels of radio

- Author: **Keith Skues & David Kindred**
- Publisher: **Amberley**
- Price: **£17.99 / $28.50**
- Release date: **Out now**

While this one is aimed directly at those with an interest in the history of pirate radio, it still does a good job of introducing the subject to those less knowledgeable. The black-and-white photographs throughout the book give a fantastic 'fly-on-the-wall' view of what life was like on the boats that broadcast the pirate stations starting in the 1960s, while Skues and

Kindred describe the lifestyle of those on board, the government's opposition (and attempts to shut the stations down), and the political movement that the presenters became part of as a result.

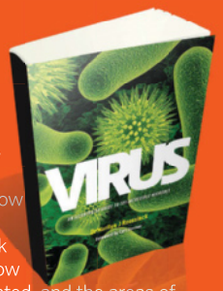
The stories, while interesting, will be most fascinating to those that lived through the era and who want more information about the stations to which they used to listen.

★★★★☆

Virus

Up close and personal with nature's incredible microbes

- Author: **Dr Marilyn Roossinck**
- Publisher: **Ivy Press**
- Price: **£20 / $35**
- Release date: **Out now**



If you like travelling, this may not be the book for you. Starting with a history of viruses, along with information about how they are studied, replicated and transmitted, Virus then moves on to talk about 101 viruses in detail, explaining how they affect the body, where they originated, and the areas of the world they impact. For some, this will be an incredibly interesting journey through the world of microbes, but for everyone else it will be a stark reminder of just how vulnerable humans are. The detail on offer is excellent, with microscopic imagery accompanying the extensive details on each species, but that doesn't stop this being one aimed squarely at those interested in viruses.

★★★☆☆

A is for Arsenic

Celebrating the use of science in Agatha Christie's masterworks

- Author: **Kathryn Harkup**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**

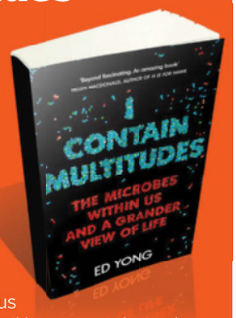
Famed author Agatha Christie was more than just a fantastic writer. If you thought she spoke to chemists when writing about the murders in her books, you would be mistaken; in fact she was a trained apothecary's assistant with an incredibly in-depth knowledge of poisons. We learn this in the introduction of Harkup's book, before motoring straight onto the main focus – the poisons themselves, and how Christie used them. Each chapter covers one of the 14 poisons that Christie wrote of, and does a great job of using Christie's novels as a launching point for deeper study. Fans of the series will love it, but there's something here for those with an interest in chemistry, too.

★★★★☆

I Contain Multitudes

A grander view of life from the viewpoint of tiny microbes

- Author: **Ed Yong**
- Publisher: **Vintage**
- Price: **£20 / $27.99**
- Release date: **Out now**



As you will learn in both this book and Roossinck's *Virus*, reviewed above, microbes are quite literally everywhere. Unlike *Virus*, however, Yong's book takes us on a trip through history, explaining in detail how co-evolution has allowed both microbes, and the beings that they live in or on, have progressed together and helped each other survive. With detours covering eminent microbiologists from history, as well as more modern microbial ecologists, the book's main goal is to take a wider view, and show that there are billions of life forms we still know nothing about.

★★★★★

Create a levitating orb

Discover static electricity's power of repulsion with this easy experiment

1 Prepare the equipment

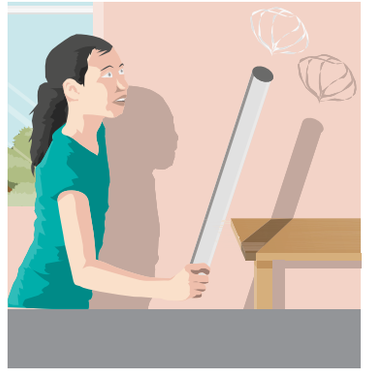
You will need a 60cm-long PVC pipe (you can buy this at a hardware shop) and the thinnest strands of Mylar tinsel you can find (try looking for Christmas decorations). The lighter the tinsel, the more likely it is to levitate successfully – one millimetre thickness is ideal. You'll also need a pair of scissors plus a head of clean, dry hair or a woolly jumper.

2 Create the orb

Lay out six strands of tinsel and knot them together at one end. Then make another knot 15cm along from the first one, cutting off any loose strands. Now, grab the PVC pipe and rub it through your hair. This is called 'tribocharging', and causes static electricity to build up on the surface of the pipe. To avoid messing up your hair, a wool jumper will work just as well.

3 Start floating

After ten seconds of rubbing, the pipe will be ready. Hold the tinsel up and bring the pipe below it. Once you release the tinsel it will first drop down on the pipe but will then rise into the air. The pipe has gained electrons from your hair, which then pass to the tinsel through electrostatic induction. The negative charges repel each other, causing the orb to float.



4 Keep the orb floating

The tinsel will turn into an orb-like shape as it rises. This is due to each single strand having a negative charge, so they all repel each other. If the orb fails to levitate it could be due to a lack of static in the pipe so try rubbing it on your hair for longer. The static charge is quite weak, so be sure to use the lightest tinsel you can find to get your orb floating.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

5 Recharge the static

As well as being repelled from the pipe, the tinsel orb will be attracted to positively charged items in its surroundings including household objects and yourself. You can repeat the floating experiment time and again until the pipe loses its electrons. This usually happens after around ten minutes of use. The pipe can then be charged again by rubbing it on your hair or a woollen jumper.

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

In summary...

Static charge is generated when a material has an unequal amount of positive charge (protons) and negative charge (electrons). This can happen when two materials rub together and the protons or electrons transfer from one to another. You may have noticed static charge making your hair stick up after sleeping in a tent!

NEXT ISSUE
- Make eggshell crystals
- Walking rainbow water

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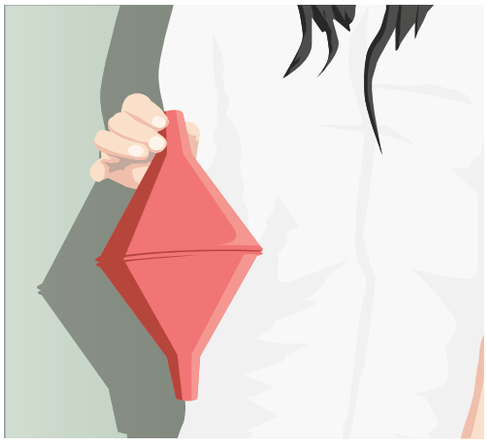
Make a funnel roll uphill

This setup seems to defy gravity, but the funnel's motion is all due to the laws of physics

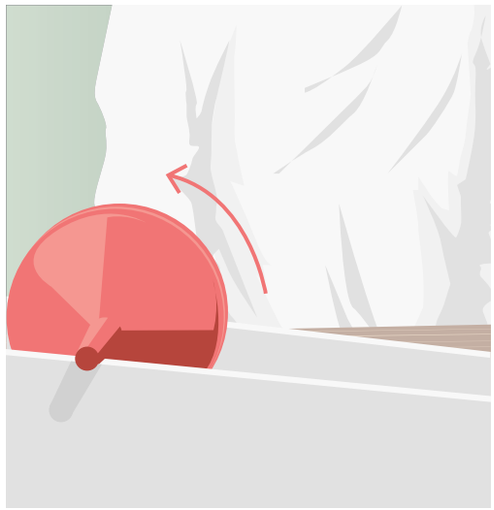


1 Tape the funnels

The first step is to gather your equipment. For this experiment you will need: two funnels of the same size and shape, two wooden boards, a thick book and plenty of tape. Lay the book at one end of the table and lay the boards on it to make a ramp. The boards need to be about 15 centimetres apart. Fasten the wide ends of the two funnels together with tape to make one object.

2 Create the ramp

Move the lower ends of the boards closer together to make the ramp V-shaped. Rest the funnels at this narrow end of the boards and let them go. The funnels will move towards the higher end of the ramp, giving the illusion that they're rolling uphill, supposedly defying gravity. Once they reach the top, you can even give them a little push downwards and they will spring back again.



3 Test the science

Despite how it looks, the funnels are still technically falling. As the two wooden boards are getting gradually wider, a narrower part of the funnels contacts them, and they drop slightly. This means their centre of mass is actually still falling towards Earth as you would expect. You can try this experiment with different equipment, to see if the effect is the same. An alternative setup is to cut two vertical slits in a cardboard box and slot long rulers in to form the ramp. How steep can you make it before the funnels stop rolling 'uphill'?

Illustrations by Ed Crooks

In summary...

The centre of mass is the point at which an object's mass is balanced in all directions. For the funnels, it lies in the centre of the circle where they are joined together. They start moving up the ramps because their centre of mass is falling due to gravity – just as Newton's law of universal gravitation would predict. The 'falling uphill' motion is just an optical illusion!

INBOX
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Letter of the Month

How strong is the Moon's gravity?

Dear **HIW,**

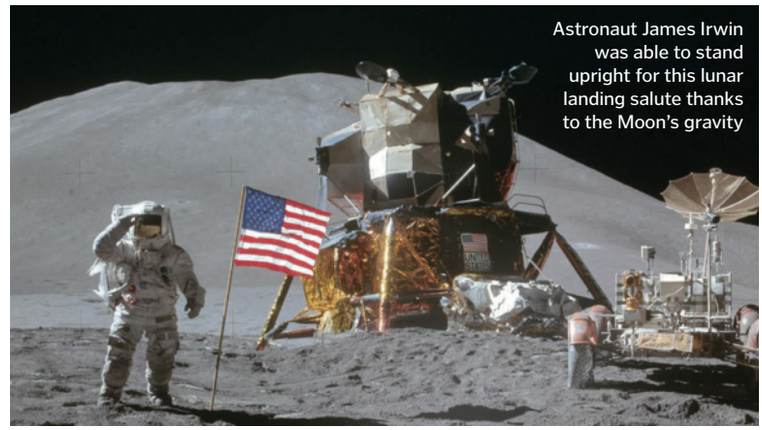
It goes without saying that your magazine is a great read every month. Having been a subscriber since day one, I have had many questions, which have eventually been answered over the years. However, I have one that remains unexplained.

When astronauts break through Earth's gravity, they are several miles high. When travelling to the Moon, how close to it would a 'weightless' astronaut have to be to feel the effects of its gravity? Or is it not felt at all?

Steve Lomax

The greater an object's mass the stronger the force of its gravity, so the Moon, which is about a quarter of the size of Earth, has gravity that is only 17 per cent as powerful as Earth's. This means the effects would be felt less by astronauts, but there would still be some effect on their bodies during both the descent to the Moon and on the surface.

A study in 2014 showed that humans need 15 per cent gravity to stand upright. That means there is just about enough to do so on the Moon, and explains why the Apollo astronauts were so prone to falling over! You could argue that 15 per cent gravity is where the astronauts are no longer 'weightless', but the exact distance from the Moon at which this happens isn't clear.



Astronaut James Irwin was able to stand upright for this lunar landing salute thanks to the Moon's gravity

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@HowItWorksmag is my new favourite magazine! I've learnt so much! I'm all set for the random questions children ask!

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@HowItWorksmag Not long until the 100th issue now :)

@ben_gray_13
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@amitkatwala
Wrote this for @HowItWorksmag about how sport changes the shape of your brain, and how that could cause the yips

@reichelt_uk
When pod-racing Star Wars-style meets F1 – it's the #Drone Racing League! Via @HowItWorksmag

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Under pressure

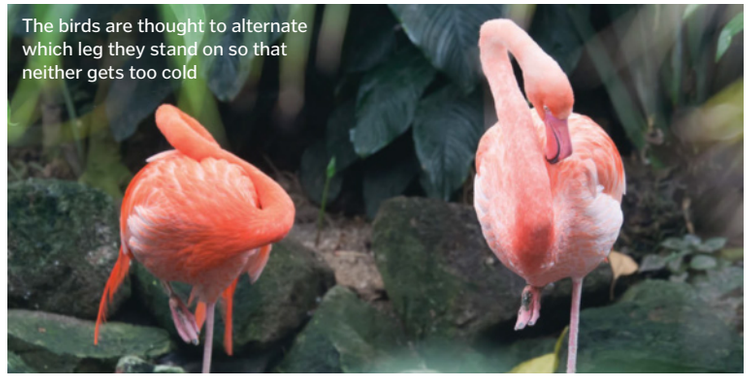
Dear **HIW,**

I love your magazine and have subscribed to it. I was just wondering what causes pressure points on your body and why some people have them and some don't?

Cosmo Maclellan (aged 12)

Pressure points are sensitive areas of the human body. They are primarily located at clusters of nerves, including at your temples, the back of your neck and the meaty part of your hand at the base of your thumb. When you apply pressure to these areas, the nerves are pushed against bone or muscle, and electrical signals are fired to the brain. This is likely to cause pain, as your body tries to restore the nerves to their normal function. However, between 10 and 15 per cent feel very little, and it's not known why.

Pressure points were used in martial arts to take down larger adversaries



The birds are thought to alternate which leg they stand on so that neither gets too cold

One-legged sleep

Dear **HIW,**

I love your magazine and haven't missed a single issue! But my question is one I have been pondering for quite a while now. Why do flamingos stand on one leg while they sleep?

Megan Tough (aged 11)

Flamingos stand on one leg more often when in water than on land, leading biologists to believe that the strange habit is to do with temperature regulation. Water draws away more body heat than air, so by keeping one leg out, awake or asleep, a flamingo will lose less heat, stopping it from getting cold and even having potential tissue damage.

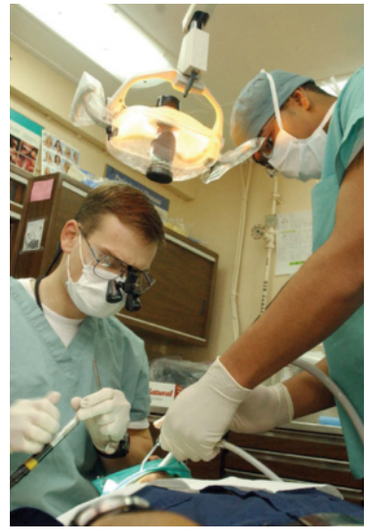
A trip to the dentist

Dear **HIW,**

I had one of my teeth out earlier this week, and they used an anaesthetic, so how exactly does this work?

Jacob Maginn (aged 11)

The anaesthetics used by dentists numb the tissue around your teeth. They do this by blocking sodium channels within the nerves so that no electrical signals are sent to your brain registering the pain. Nerve conduction is blocked until the anaesthetic is chemically broken down by your body's defence systems and feeling returns to the area. The anaesthetic used by your dentist when you had your tooth out is likely to have been lidocaine.



Lidocaine is known as a vasoconstrictor, as it contracts blood vessels

HOW IT WORKS

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BIG CAT ATTACK

The fierce felines at the top of the food chain

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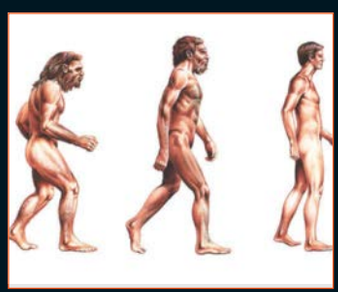
- On the hunt: stalking and catching prey
- Life in a lion pride

Could we survive on the Red Planet?



Discover evolution, the misunderstood theory

What tech will drive the cars of tomorrow?

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FAST FACTS

Amazing trivia to blow your mind

68,000 boxes of candyfloss were sold when it was first introduced at the 1904 St. Louis World's Fair

38KG
THE AMOUNT OF BAMBOO A GIANT PANDA CAN EAT PER DAY

FLEAS CAN JUMP 100 TIMES THEIR OWN HEIGHT

2.5 MILLION LIGHT YEARS
THE CURRENT DISTANCE BETWEEN THE MILKY WAY AND THE CLOSEST MAJOR GALAXY, ANDROMEDA

100 TRILLION
THE NUMBER OF NEURAL CONNECTIONS IN THE HUMAN BRAIN

A cockroach can live for weeks without a head

YOUR HEART PUMPS OVER 9,000 LITRES OF BLOOD EACH DAY

600 MILLION TONS
THE MASS OF HYDROGEN CONSUMED BY THE SUN EVERY SECOND

62
THE NUMBER OF KNOWN MOONS ORBITING SATURN

SMILING RELEASES ENDORPHINS THAT MAKE YOU FEEL HAPPY, EVEN IF YOU'RE FAKING IT

32,000KM
THE DISTANCE MARCHED BY THE ARMY SERVING UNDER ALEXANDER THE GREAT

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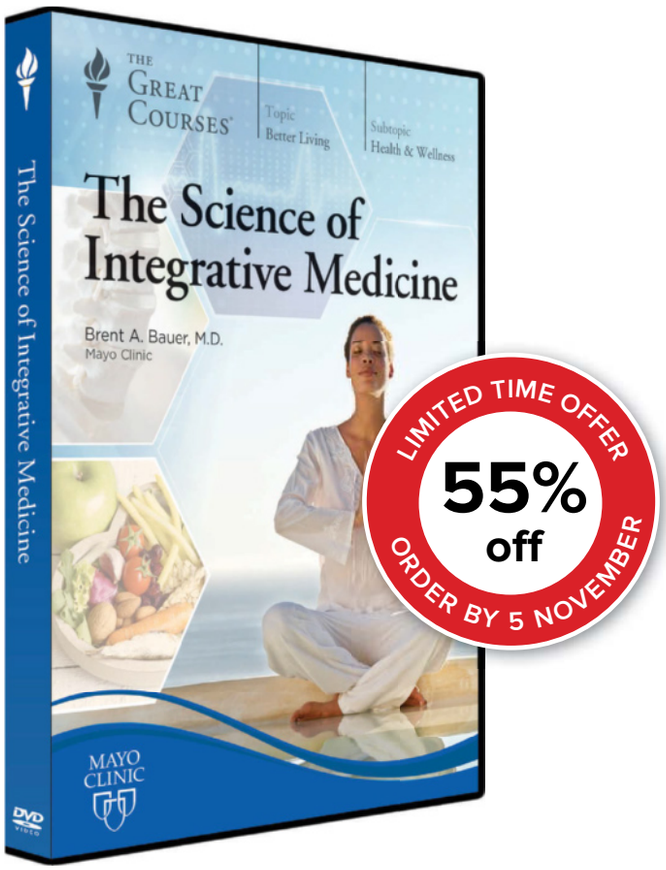

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